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SHORT-PERIOD PULSATIONS OF THE EARTH'S ELECTROMAGNETIC FIELD

COLLECTION OF ARTICLES

A. G. Kalashnikov and V. A. Troitskaya, Editors

IGY Program, Section III, No. 3,
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I. SHORT-PERIOD PULSATIONS OF THE EARTH'S MAGNETIC FIELD

by V. I. Afanas'yeva

Even before the International Geophysical Year (IGY) began, when its program was only being determined, we began to study the short-period pulsations (SPP) of the geomagnetic field according to the data available at that time. We hoped to look into at least some of the problems in the morphology and physics of short-period pulsations in order to make fuller use of the IGY data.

The main conclusions of our work are based on study of the conventional magnetograms of four Soviet observatories: Pavlovsk, Nizhnedevitsk, Srednikan and Vladivostok. These observatories in pairs have a significant coverage in longitude and a certain coverage in latitude. In the course of the work we were able to acquire the magnetograms of certain other observatories (see Appendix). In the magnetograms 20 mm corresponds to an hour of time while 1-2-4 gamma is equivalent to a millimeter of the ordinate. This limited us in our study of pulsations by periods. All of the following concerns pulsations with periods of approximately 30 to 240 sec and with amplitudes of not less than 1 gamma.

First of all, lists were compiled in which the short-period pulsations were set down hour by hour. It was at once decided to differentiate between pulsations lasting more and less than an hour. Furthermore, we used international terminology: one type of pulsation may be identified with pc, and the other with pt. In all, our lists encompassed aroung 180,000 hours of time at various observatories (more than 20 observatory-years). This material allowed us to carry out a number of statistical studies. The following results were obtained.

Diurnal Distribution of pc -- S (pc). 1. S(pc) takes place according to local time. The maximum at the middle latitudes is at 1100-1400 hours (Figure 1). At the geomagnetically more northern observatories a second maximum at 0500-0600 hours is observed (Leningrad, sometimes Nizhnedevitsk). At Lovozero this maximum occurs even in the earth currents.

2. The form of S(pc) does not depend on the season. During the night hours pc, as a rule, are absent. In the winter the period without pulsations is longer than in summer, but this is not proportional by latitude (Figure 1).

3. The form of S(pc) does not usually depend on the level of magnetic activity. Only on very disturbed days does the number of

pulsations during the morning hours in Srednikan increase and the form of S(pc) approximate the Leningrad form.

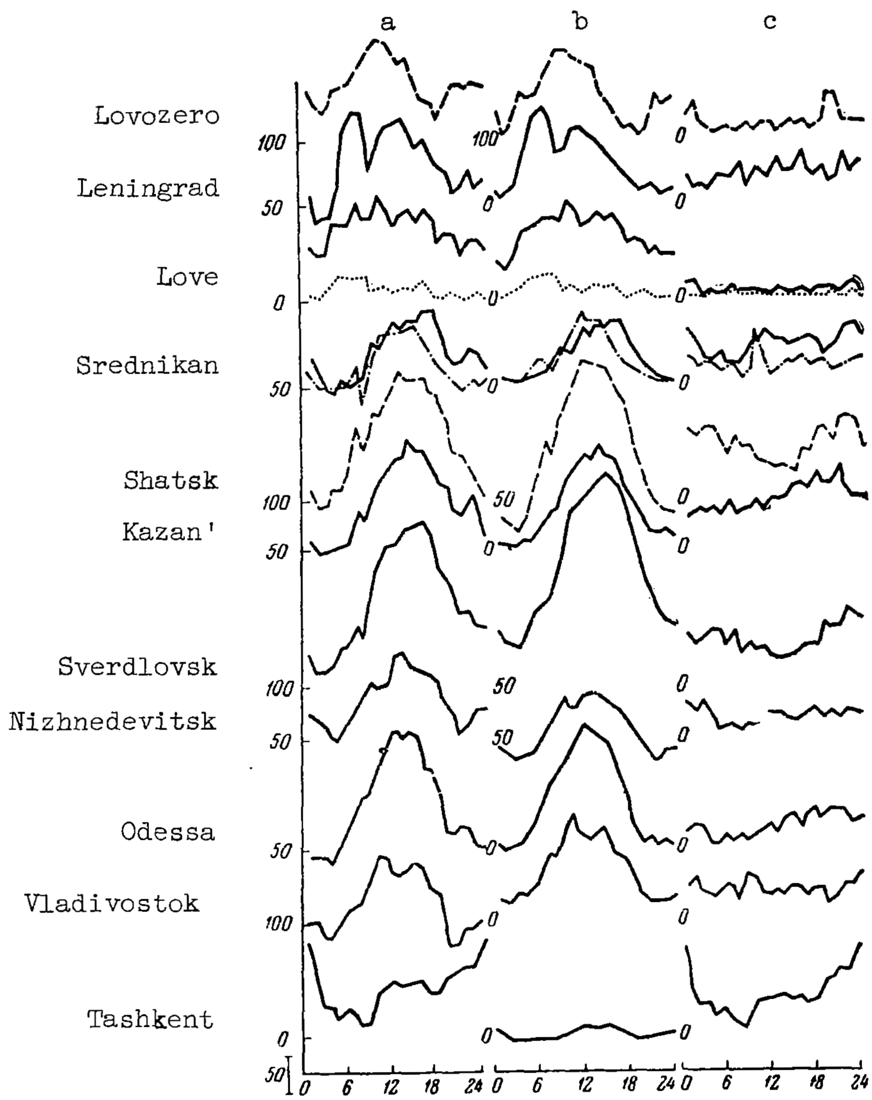

Figure 1. Diurnal distribution of SPP of varying duration.

a = pc + pt; b = pc; c = pt. The numbers on the curves show the number of cases in excess which the distribution of SPP is expressed by a curve that is characteristic of the diurnal distribution of SPP.

4. With an increase in activity of the day or year, as a whole the maximum of S(pc) is shifted from the afternoon to the pre-noon hours

(Figures 1 and 2).

5. The number of hours with pc increases to the south.

6. On days of any activity, the number of pc during the summer is greater than during the winter.

Distribution of pt by Days - S(pt). 1. The maximum in the middle latitudes is at 2000-2400 hours, local time. At the geomagnetically more northern geomagnetic observatories (Srednikan and Leningrad), no precise maximum is observed for S(pt) (Figure 1).

2. The form of S(pt) does not depend on the season.

3. The form of S(pt) does not clearly depend on the level of magnetic activity.

4. The number of hours with pt during the hours of the maximum increases to the south.

5. The number of pt is greater in winter.

6. With an increase of activity in a cycle, the maximum of cases of pt shifts from 2000 hours to midnight (Figure 2).

Comparison of S(pc) and S(pt). Around 80-90 per cent of all the days contain pc in a given hour, whereas pt are observed only in 30 per cent of the cases.

Distribution of pc by Season. The seasonal distribution of pc is not clearly similar to the seasonal distribution of magnetic activity. From among 18 observatory-years, in 11 years the pc are more frequent during the spring equinox. There are years with a maximum of pc during the summer; this is analogous with the distribution of magnetic activity in years with low activity (according to the K-index).

Very Long pc. Among the pc class, pulsations were distinguished lasting five hours and more in succession (up to 20). A decrease of amplitudes during the night hours (local time) is characteristic for them (Figure 3). The majority of them were noted during a year of reduced activity in the cycle (1952).

Comparison with Ionospheric Data. A similarity of the forms of S(pc) and S(f_oF2) can at once be seen. This prompted a study of the correlations of pc with the parameters of the F2 layer. The correlation of S(pc) and S(f_oF2) was high: about 0.97 during the equinox, 0.88 in winter, and 0.74 in summer (data are presented for Sverdlovsk, Figure 4).

Of special interest is the similarity of S(pc) of Leningrad with S(f_oF2) of Tiksi in the absence of similarity of S(pc) of Leningrad with S(f_oF2) of Leningrad (Figure 5).

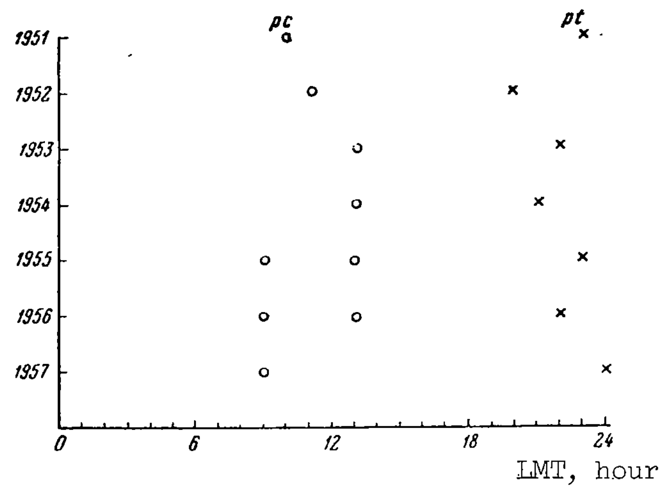

Figure 2. Shift of the maxima of pc and pt by 24-hour periods in a number of years of solar activity (Kazan'). 1955 and 1956 each have two equal maxima.

Data on Earth Currents. S(pc) of Leningrad has two maxima--midday and morning. To explain the geographic pattern, use was made of data on earth currents from Shatsk and Lovozero. The S(pc) of earth currents for Shatsk turned out to be similar to the S(pc) of the middle latitude magnetic observatories. The S(pc) of earth currents in Lovozero has only a morning maximum. Consequently, north of Leningrad the midday maximum of pc becomes less than the morning maximum. It is interesting to note that the morning maximum of S(pt) in Srednikan corresponds with respect to time to the morning maximum of S(pc) in Leningrad. This indicates that with an increase in the geomagnetic latitude, the morning maximum is composed of more stable pulsations, i.e., to the north the stability of the pulsations increases according to the time.

Interpretation of the Results. Short-period pulsations (SPP) are a manifestation of the electromagnetic pulsations of the external atmosphere of the earth. However the disclosed SPP regularities indicate that not all of the outer atmosphere, concentric about the earth, acts in the same way to promote the appearance of SPP. One can say that

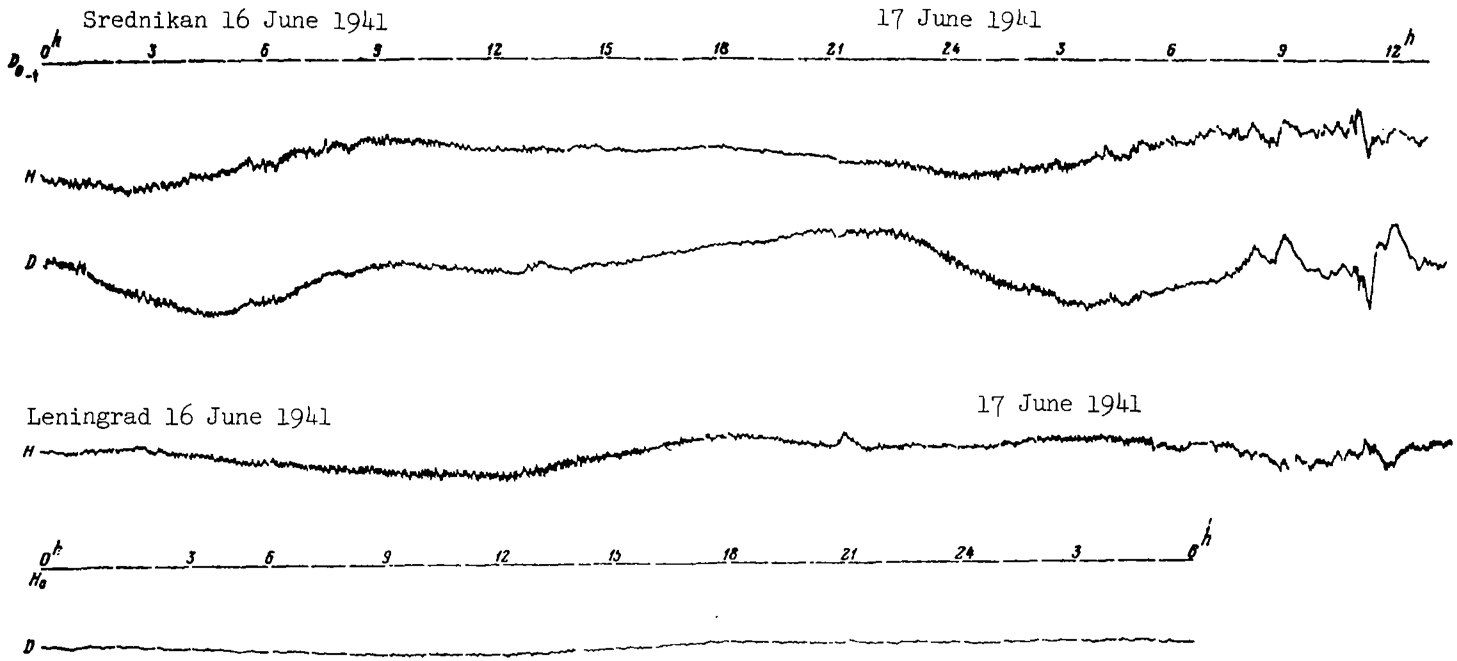

Figure 3. Long-term pc pulsation. Magnetogram of 16-17 June 1941.
(Srednikan and Leningrad)

in the entire outer atmosphere there are certain regions in which ionization is sufficiently high so that pulsations in these regions create SPP on the earth. There are at least three such regions. One is at the daytime middle- and low-latitude portion of the earth; it contributes to the origin of the around-midday maximum of pc. Ionization here is created by the wave radiation of the sun. The second region of increased ionization is over the morning high-latitude area of the earth. Here ionization is probably created by the corpuscular radiation of the sun. The third region is over the night side of the earth over the middle, subarctic latitudes. Ionization in this region probably is likewise of corpuscular origin.

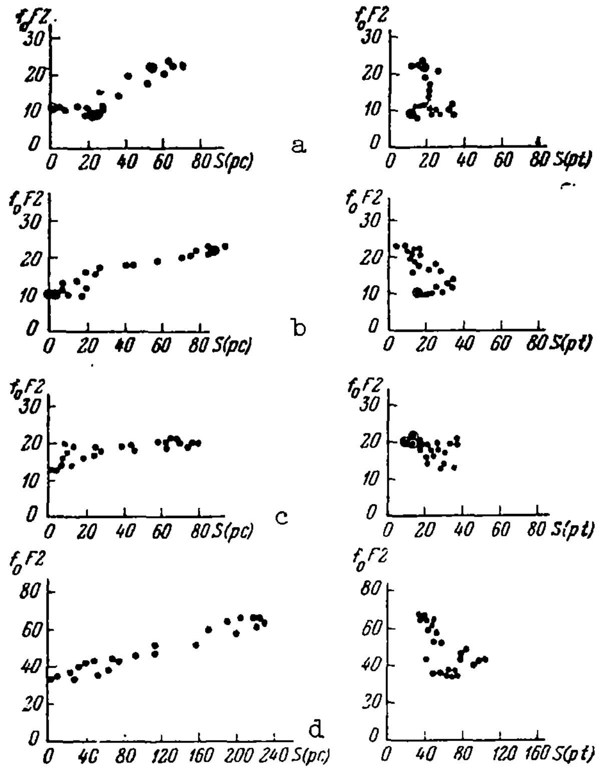

Figure 4. Correlation of the shapes of the diurnal distribution of pc and pt and the critical frequencies of f_oF2 (Sverdlovsk, 1954). The number of cases of pc or pt at the corresponding critical frequency f_oF2 is set forth on the abscissa.

a - winter; b - equinox; c - summer; d - year.

The first region, apparently, always exists; the two others exist only during the periods of action upon the earth of solar corpuscular streams, whose energy enriches the periphery of the region of daytime wave ionization.

What causes pulsations in these three regions? Undoubtedly, the interaction of the geomagnetic field with the electromagnetic phenomena in the interplanetary medium in the vicinity of the earth. This interaction may occur as the introduction of a corpuscular stream into the earth's atmosphere (whereby pt pulsations arise). It may also be the interaction of corpuscular clouds (residues of previous streams in the interplanetary medium), penetrating into the high latitudes of the earth, through which the earth passes while moving in orbit. In such cases the motion of the earth in orbit still does not provide sufficient energy for the emergence of pc-type pulsations. One must assume that in this space there are velocities in the order of 300 km relative to the earth. Therefore, according to the theory of Kato and Akasofu, one can conclude that the earth receives energy from corpuscular space sufficient to create pc with an amplitude in the order of 5 gamma. So, pc and pt are probably created under the effect of two different causes; pc--under the action of "slow," weak clouds or streams to the daytime region of increased ionization in the atmosphere; pt--under the action of corpuscular streams to the evening and morning high-latitude regions of increased ionization created and accelerated by the same streams.

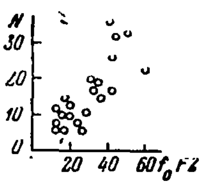

Figure 5. Correlation of the critical frequencies of f_oF2 (Tiksi, 1948, January) and the total number of hours N with pc pulsations (Leningrad, 1936, winter).

Over Leningrad and Tiksi, from the viewpoint of the mechanism for the origin of SPP, the ionosphere is identical, but there is a screen over Leningrad which does not exist over Tiksi and which creates a pattern of $S(f_oF2)$ which disturbs the correlation of S(pc) with $S(f_oF2)$, that is so high in Tiksi.

In the statistics of the SPP, the chief contribution is made not by pt but by pc. But if we assume that the latter are created by matter almost constantly present in the vicinity of the earth, it becomes clear why S(pc) does not depend on the magnetic activity.

We did not devote much attention to the question of the sizes of the pulsation periods. Nevertheless, having examined the various conclusions of the theory of pulsations proposed by the Japanese geophysicists, we turned our attention to the fact that if one assumes that the SPP are created not only by corpuscular streams encountering the earth head-on, but also by those passing around the earth at a close distance, then one must expect a predominance of SPP with periods of from 1 to 2 minutes. Some statistics on the question of the relative frequency of various pulsation periods indicate the validity of such a conclusion. Among 241 cases of periods from 30 to 240 seconds, only in 11 cases were the periods shorter than 1 minute, and in 47 cases were longer than 2 minutes.

APPENDIX

List of observatories whose data are used in the report.

Station	Latitude (Geomag) Φ, n	Longitude (Geomag) Λ	Year	Source Materials
Lovozero (Lov)	63.0	126.1	1953	Earth currents
Tiksi	60.4	191.3	1948	Ionosphere
Love (Lo)	58.1	105.8	1957	Magnetic field
Leningrad (Ln)	56.0	117.0	1938	" "
Srednikan (Sr)	53.2	210.5	from 1938 to 1954	" "
Kazan' (Ka)	49.3	130.4	1954	" "
Shatsk (Sha)	48.7	123.7	1954	Earth currents
Sverdlovsk (Sv)	48.5	140.7	1954	Magnetic field
Nizhnedevitsk (Nzh)	46.9	119.6	1938	" "
Odessa (Od)	43.8	110.9	1952	" "
Vladivostok (Vl)	32.9	198.0	1938	" "
Tashkent (Tsh)	32.4	143.8	1954	" "

II. ON CERTAIN REGULARITIES OF THE DISTURBED FIELD OF EARTH CURRENTS

by V. V. Kebuladze

Study of the structure and changes of the electrical field of earth currents is of considerable importance in establishing the causes of these variations and their dependence on various geophysical phenomena.

The spectrum of the variable portion of an electrotelluric field is characterized by a wide range. The possibility of observing and studying individual components of this spectrum depends on the amplitude-frequency characteristic of the registering apparatus and the running rate of the recording. Thus to isolate and study the general regularities of an electrotelluric field, it is of decisive importance to correctly select the apparatus parameters and to have an identical observation method for the various points. The difficulty connected with the classification of field pulsations of various types is, in our opinion, caused basically by differences in the parameters of the apparatus used, and by the effect of local factors. We have isolated and studied the following types of variation most accurately observable in the recordings of earth currents: 1) storms and disturbances of long duration; 2) short-period disturbances of stable conditions (pc) and pulsation trains (pt).

Below are presented the main characteristics of these disturbances, and certain regularities are set forth which were noted by us as a result of statistical reduction of the continuous recordings made by the Dusheti Electrotelluric Station of the Institute of Geophysics, Academy of Sciences Georgian SSR during the period of 1948-1958 (Refs. 1-6).

Long-running Electrotelluric Storms and Disturbances

Under this designation are grouped all electrotelluric disturbances (with the exception of individual bays and impulses) lasting from 3-4 hours to several days. Here are included violent, moderate, and weak disturbances with gradual and with sudden beginnings. Each long-running storm consists of various pulsations of regular and irregular form, of alternating bay-shaped disturbances, sharply expressed individual impulses and short-period pulsations. Such storms and disturbances are easily and reliably detected on slow registrations (20 and 90 mm/hour).

To establish the regularities in the course of electrotelluric activity, tables were compiled of the hourly three-point characteristics according to the month, season, and year; a catalog was also compiled of the electrotelluric storms and disturbances noted in Dusheti in the 1948-1958 period (Ref. 7). According to the hourly three-point characteristics, the field was considered quiet if in the duration of the examined time period (for example, one hour), the amplitudes of the variations of one or both EW and NS elements were less than 5 mv/km; moderate disturbance was when the amplitudes of the variations changed within the limits of 5-15 mv/km, and if they exceeded 15 mv/km the disturbance was violent. With the aid of these tables the diurnal, seasonal, and yearly variations of disturbed hours were studied, and the activity of each day during the 11-year period of observations was evaluated as well.

In the catalog compiled by us, 708 storms and disturbances are included among which 146 were violent, 179 were moderate and 383 were weak. The isolation and study of these storms and disturbances was conducted on the latitudinal element, since at Dusheti it is more disturbed than is the meridional one. In the catalog are presented the following basic characteristics of long-running electrotelluric storms and disturbances: the number of disturbances by months and years; the beginning, end, and duration (in hours) of each disturbance; the beginning and end of the active periods, and the general characteristics of a given disturbance. In compiling the tables of the hourly three-point characteristics from the catalog, all disturbances were excluded which were due to thunderstorm phenomena and other local disturbances.

As a result of the statistical analysis of the data of the tables for the hourly three-point characteristics and of the catalog, the following regularities were established.

1. In the overwhelming majority of cases, the disturbed pulsations in storms having a sudden beginning have higher amplitudes than do the ones in storms with a gradual beginning.

2. The duration of individual distrubances changes within a wide range, from several hours to several days. However, disturbances and storms lasting more than 3 days were comparatively rare. From 1948 to 1958, a total of 22 such cases out of 708 disturbances were noted in Dusheti.

3. A definite regularity in the distribution of beginnings, endings and active periods of electrotelluric disturbances was noted. The largest number of disturbances begins during the period from 0400 to 1800 hours with a maximum between 1300 and 1400 hours, according to universal time. A large number of the beginnings also occur during the period between 0500 and 0700 hours. Between 1800 and 0400 hours they are observed comparatively rarely. The period from 0200 to 0500 hours is characterized by minimum activity. The majority of the electrotelluric storms and disturbances end between 2100 and 2300 hours (Figure 1).

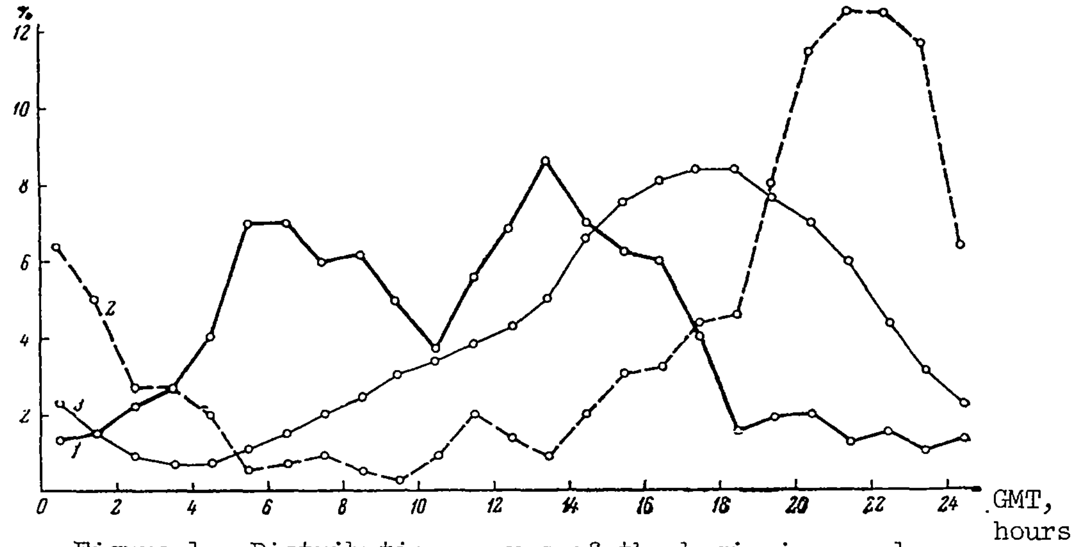

Figure 1. Distribution curves of the beginning, end, and active periodsof electrotelluric storms and disturbances in the course of a 24-hour period.
1 - beginning; 2 - end; 3 - active period

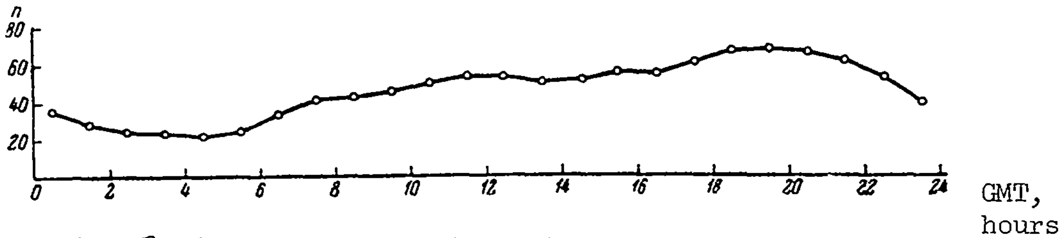

Figure 2. Mean curve of the diurnal variation for 1948-1958.

4. With the help of the hourly 3-point characteristics, the diurnal variation of the frequency of disturbed hours is clearly apparent. The second half of the day is characterized by increased activity in comparison with the first. The maximum number of disturbed hours is noted between 1800 to 2100 hours, and the minimum from 0400 to 0600 hours, according to universal time. The form of the diurnal variation is steadily repeated from year to year. The curves of the diurnal variation obtained in the various years and the average yearly curve for 11 years (Figure 2) agree well with each other. The maxima and minima of the frequency of electrotelluric disturbances in the diurnal course occur at almost the same times for all the years examined.

5. The data from the catalog and the hourly three-point characteristics made it possible to isolate the yearly variation of the frequency of appearance of electrotelluric disturbances. The largest

number of long-running storms and disturbances occurs during the equinoxal months, while the lowest number occurs during the months of the summer and winter solstices (Figure 3). It was established that June and July are characterized by a minimum of activity.

Figure 3. Average yearly variation of electrotelluric disturbances for 1948-1958.
1 - according to the individual storms and disturbances; 2 - according to the hourly three-point characteristics; 3 - number of electrotelluric storms and disturbances; n - number of cases.

6. The maximum activity of the electrotelluric field was noted in 1951, 1952, and 1956, and the minimum activity in 1954 and 1955; this is in complete accordance with the course of the latest cycle of solar activity (Figure 4).

7. In spite of the somewhat relative nature of activity evaluation by means of hourly three-point characteristics, it can be maintained that their use permits a number of regularities in the behavior of the electrotelluric field to be isolated. The curves of the average yearly course of activity of the electrotelluric field (Figure 3), plotted on the basis of the data in the catalog (Ref. 1) and the hourly characteristics (Ref. 2), agree well among themselves.

Short-Period Disturbances of Stable Conditions and Pulsation Trains

The observation, isolation, and accurate classification of the individual types of short-period disturbances constitute a more complex task than the study of long-running electrotelluric storms and disturbances.

The investigation of short-period disturbances of stable conditions (pc) and pulsation trains (pt) on the basis of our registrations became possible in 1951 after the sensitivity of registration was increased (to 0.1-0.15 mv/km) and a conversion from 20 mm/hour to 40 and 80 mm/hour running was effected.

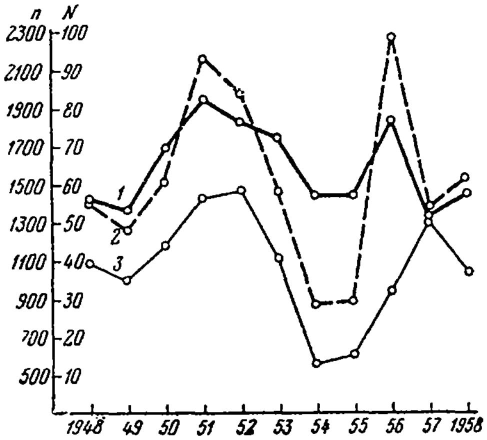

Figure 4. Average yearly variation of the activity of the electrotelluric field for 1948-1958.
1 - number of electrotelluric storms and disturbances (N); 2 - number of disturbed hours (n) according to individual storms and disturbances; 3 - number of disturbed hours (n) according to the hourly three-point characteristics.

The diurnal, seasonal and yearly distributions of pc and pt were studied on the basis of the round-the-clock registrations made at the Dusheti station in 1951-1958. On the basis of the rapid registrations of 1957-1958, the limits of variation of the periods and amplitudes of these pulsations were also determined.

As a result of the statistical reduction of the 24-hour tellurograms for 1951-1958, the following regularities were established (Ref. 8).

1. The amplitudes of pc at Dusheti change from tenths to several units of mv/km. Pulsations with periods of 15-25 seconds were noted most frequently of all.

2. The maximum amplitudes of pc reached 10 mv/km and their period was in the order of 60-80 seconds.

3. Pc pulsations have a clearly expressed diurnal variation. The largest number of hours with continuous pulsations from year to year was noted in Dusheti from 0400 to 1800-1900 hours according to

universal time (Figure 5).

Figure 5. Mean curve of the diurnal variation of pc for 1951-1958.

4. The average seasonal curves of the diurnal variation of pc indicate that the number of hours with the greatest values of continuous pulsations decreases in the winter months, and increases in the summer. This leads to the concept of the influence of direct solar radiation on pc.

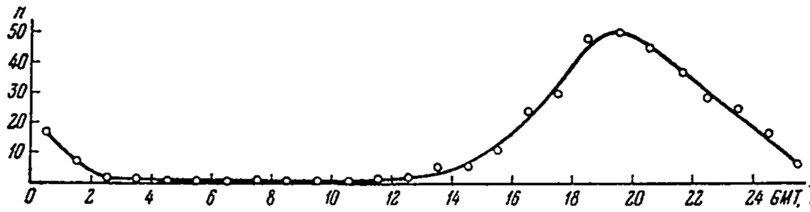

Figure 6. Mean curve of the diurnal variation of pt for 1951-1958.

5. According to our data, clearly expressed yearly variation of pc is not observable.

6. The average yearly curve for the diurnal variation of pulsation trains for 1951-1958 (Figure 6) indicates that they almost never appear between 0200 and 1400 hours according to universal time. The frequency of appearance of pt after 1500-1600 hours sharply increases and a maximum is reached between 1800-2100 hours, after which it gradually decreases. Such a regularity in the diurnal variation of pulsation trains is repeated from year to year.

7. Upon comparing the corresponding data it was established that pulsation trains at Dusheti have the same average yearly diurnal variation as at points examined by other researchers.

8. The average yearly diurnal of pt variation (Figure 6) agrees fairly well with the distribution for the active-period days of long-running storms and disturbances (see Figure 1). The largest number of pulsation trains, as a rule, is coordinated with the maximum development of activity of the electrotelluric field.

9. The yearly course of pt pulsations is weakly expressed. According to the average values for 1951-1958, a certain increase in the quantity of pulsation trains in March and April is noticeable.

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III. REGULARITIES IN THE EXCITATION OF SHORT-PERIOD PULSATIONS IN THE MIDDLE LATITUDES

by

M. V. Okhatsimskaya, Yu. B. Rastrusin, I. I. Rokityanskiy and R. B. Shchepetnov

Study of the short-period pulsations (SPP) of the field of the earth's currents, conducted during the IGY at the middle-latitude stations of the Institute of Physics of the Earth, Academy of Sciences USSR, permitted us to isolate a number of general regularities in the excitation of SPP for the middle latitudes of the Soviet Union.

Investigations were conducted over a vast area which, in longitude, encompasses more than 1/3 of the globe. The stations were variously located. Two of them, Borok and Alma-Ata, are intra-continental and two, Petropavlovsk-Kamchatskiy and Alushta, are located respectively near the Pacific Ocean and the Black Sea. All of this allowed us to affirm that the regularities isolated are sufficiently characteristic for the middle latitudes in general.

The data from the analysis of the registrations of earth currents from all the stations confirmed the existence of two pulsation regimes for the field of earth's currents—continuous pulsation pc, and train-type pulsations pt. Pulsations of the first regime have periods of 15-40 seconds; once begun, they continue for hours. They appear in the daylight hours of local time. Pulsations of the second regime appear during the night hours of local time in the form of individual groups, or in series of groups with periods of 50-90 seconds and a total duration of from several minutes to several hours.

Previous investigations on the time control of these two regimes led to the concept of their possible subordination to universal time. Such a concept could be formed on the basis of the following circumstances: first, the diurnal variations of SPP were compared on the basis of stations located close to each other with respect to longitude; second, indistinct maxima were compared which were obtained from a small number of cases; this did not permit us to isolate the longitude effect of the displacement of maxima even for stations substantially removed from one another. In addition to this, in both regimes pulsations undoubtedly exist which appear according to universal time. Such cases, as a rule, are more intensive even though the number of them is comparatively small. It is natural that in the first stages of the study of SPP, cases of this nature attracted more attention and were one of the reasons for the concept of universal time as a basic controlling factor in the excitation of SPP.

The data obtained at the four middle-latitude stations for the period of the IGY indicate with certainty the connection of the excitation of short-period pulsations with solar illumination, where the basic controlling factor is local time. Thus, steady pulsations which are stimulated during the daylight hours attain a maximum around the local midday. Pulsation trains, which pertain to night hours, attain a maximum around the local midnight. The direct connection of the SPP with illumination is confirmed by the seasonal variation: the maximum number of cases of their appearance occurs during the summer period, with a minimum during the winter. The observed effect of the polar night in the Antarctic once again confirms this connection. What has been said above concerns chiefly pc, since, besides the diurnal variations, there are no facts to confirm a principally nocturnal excitation of pt.

The following feature characterizing the middle latitudes is the comparatively small amplitude of the short-period pulsations, which for pc are measured in terms of millivolt fractions and millivolt units, and for the pt pulsations in terms of one to ten millivolts per kilometer.

Study of the frequency spectrum indicates that at all of the middle latitude stations periods of 15-30 seconds predominate for pc, while periods of 50-90 seconds predominate for pt. In general these periods encompass more than half of all of the examined cases. Periods of less than 15 seconds and more than 30 for pc, and of less than 50 seconds and more than 90 for pt characterize the middle latitudes but little.

Diurnal course of pc and pt.

The diurnal variation of short-period pulsations of the pc- and pt- type was plotted for all four stations on the basis of results of the primary reduction of tellurograms for the 18 months of the IGY (July 1957—December 1958). The number of cases of pc registered for each station, amounted on the average, to more than 5,000, and for pt to more than 400. Processing of the material and the plotting of graphs at each station was carried out according to a single set of instructions by various workers independently of one another.

In Fig. 1 summary graphs are presented for the diurnal courses of pc and pt, combined for convenience of examination. For pc and for pt the graphs were plotted according to local and universal time (the abscissa axes). Along the ordinate axes, in all cases, are plotted the number of hours, n, in which cases of the appearance of pulsation have been registered.

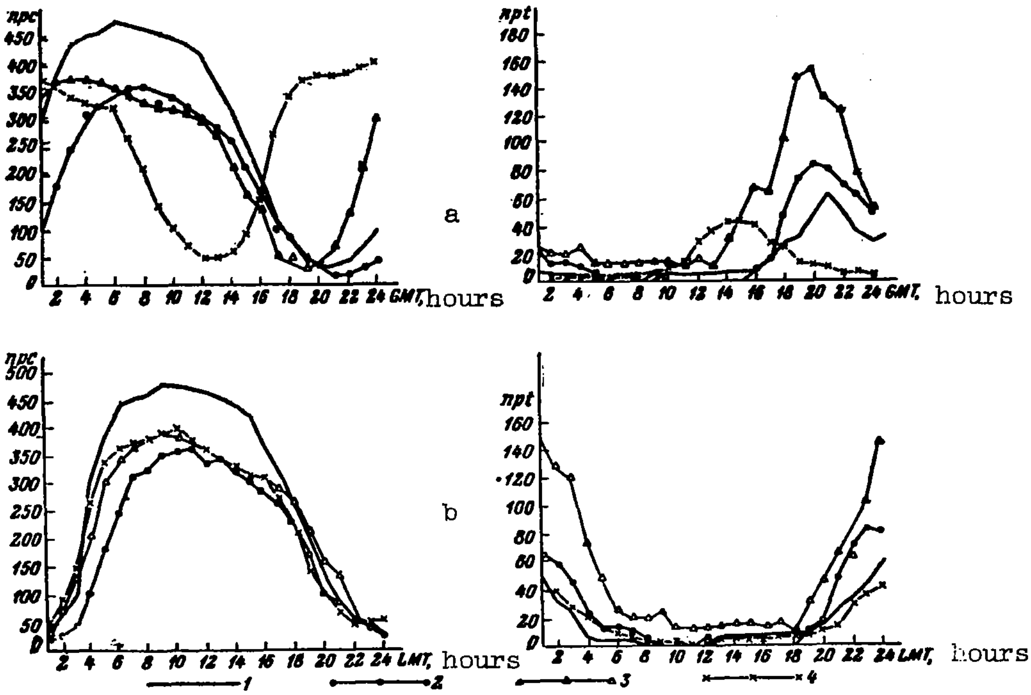

Fig. 1. Summary diurnal variation of pc and pt (June 1957-December 1958).
a-graphs plotted according to universal time; b-graphs plotted according to local time; 1-Borok; 2-Alushta; 3-Alma-Ata; 4-Petropavlovsk-Kamchatskiy.

Upon examination of the graphs plotted according to universal time, the shift of the extremal values of the quantities of pc and pt towards midnight is clearly seen. This displacement is all the greater, the further west the point of observation is situated, and the difference in the hours of onset of the corresponding extremal values for the different stations is equal to the difference in local time. Hence, it follows: 1) the onset of the maximum or minimum of a regime of SPP in terms of universal time depends upon the longitude of the observation point; 2) the diurnal variation of pc- and pt- type pulsations is controlled by local time.

The graphs plotted according to local time indicate a very strong coincidence of the diurnal variation curves for all stations, the difference in the curves being related, apparently, to the greater

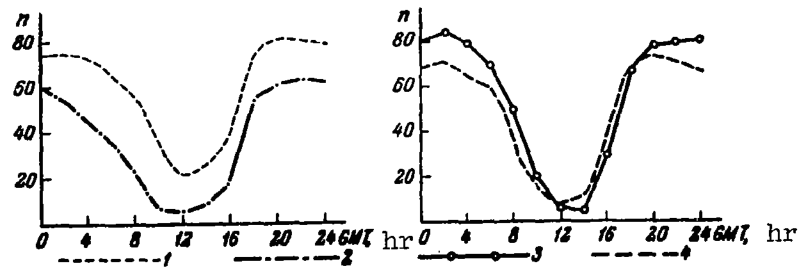

Fig. 2. Diurnal variation of pc at the Petropavlovsk-Kamchatskiy station.
1-summer 1958; 2-winter 1957-1958; 3-autumn 1958;
4-spring 1958.

or lesser number of cases considered. Analysis of the diurnal variation curves of pc confirms the data presented by V. A. Troitskaya on the sharp climb of the left slope of the curve and its more slanting descent. In our case, the angles of inclination of the curves have a ratio to one another of 1 : 1.5 which attests to the rapid excitation of the continuous pulsations, and to the slower process of their attenuation. A like analysis of pt is difficult to carry out because of the relatively small number of cases and the resulting indistinctness of the diurnal variation curves.

In general the law for excitation of the SPP (pc) is depicted in the following form: their number sharply increases beginning at 0300-0400 hours, local time, and forms a broad maximum which encompasses all the daytime hours. Thus, the maxumum of pc occurs 8-10 hours after the moment of their minimum appearance. The curve descends slowly, and the minimum is reached 14 hours later, at approximately midnight, local time.

The diurnal course of pt-type pulsations is opposite in character. The maximum of pulsations here occurs at local midnight, and the minimum at midday.

Proceeding from the dependence of the SPP excitation on illumination, one should expect seasonal changes in the diurnal distribution. The regularity in the seasonal variation of the diurnal variation of pc, general for all stations, is presented for the Petropavlovsk-Kamchatskiy Station where it is more clearly expressed (Fig. 2). From the graphs it can be seen that the summer curve is situated higher, while its nighttime minimum is the narrowest. The winter curve, conversely, has a low position with a broad nighttime minimum. The curves for the equinoxes have an intermediate position and practically coincide with one another.

No regularity whatsoever is manifested for pt in the seasonal change of the diurnal variation at any of the stations.

Distribution of pc and pt according to periods and amplitudes.

As the study of the frequency spectrum of the pulsation regimes of the field of the earth's currents indicates, the percentage ratio of pulsations of various periods is approximately the same for each of the stations.

For all stations, in general, the maximum is the number of pc with periods from 15-30 seconds; this amounts to 80 percent of the total number of cases (22,550) considered. For pt the maximum number consists of pulsations with periods from 50 to 90 seconds: around 60 percent of the entire number (2,270) of the examined cases (Fig. 3).

The limits of the most probable values of the amplitude gradients for pc and pt for each station are presented in Table 1.

Station	Amplitude Gradients, mv/mm	
	pc	pt
Borok	0.3-0.5	1.0-1.5
Alushta	2.0-2.5	10.0-15.0
Alma-Ata	0.7-2.0	2.0-5.0
Petropavlovsk-Kamchatskiy	0.5-2.5	4.0-8.0

Table 1

From this table it can be seen that the amplitude gradients are higher for the coastal stations than for the inner-continental stations.

In addition to frequency-amplitude analysis, the study of the predominant direction of the flux of the earth's currents was made at the middle-latitude stations. This preliminary study was conducted chiefly on the basis of excitations of the sudden commencement type (ssc) and bay-like excitations (b). The values of the angles and the directions of earth-current flux for the various stations are presented

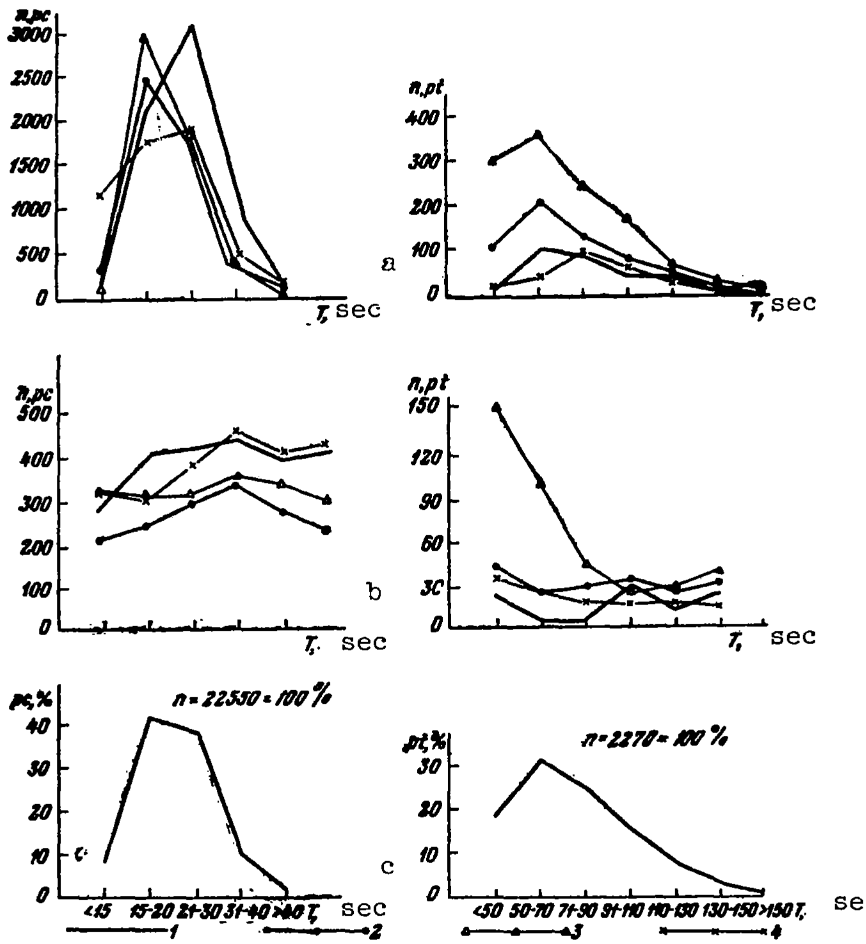

Fig. 3. Distribution of pc and pt.
a-overall distribution according to period; b-average distribution according to season; c-percentage distribution according to period.
The arbitrary designations are the same as in Fig. 1.

in Table 2.

For the shore stations the flux of the earth's currents has a tendency to the direction perpendicular to the shoreline.

Seasonal variation of pc and pt.

Study of the seasonal variation of SPP at all of the

Station	Direction
Borok	N 34°E
Alushta	N 45°W
Alma-Ata	N 48°W
Petropavlovsk-Kamchatskiy	N 70°W

Table 2

middle-latitude stations did not disclose an entirely unequivocal dependence of changes in the quantity of SPP on the time of year. Whereas it is still possible to speak of a definite tendency toward more frequent appearance of pc in the summer, no kind of regularity is observable for pt.

Taking into account a direct connection between the excitation of SPP and solar illumination, it becomes clear that the seasonal changes in the SPP are manifested less and less from the poles toward the equator. Hence it follows that the indistinctness of the seasonal variations of SPP in the middle latitudes is completely in order. It is apparently this fact which explains the contradictory data advanced by various researchers. It is quite possible that a clearer pattern of the seasonal changes in the SPP will be provided not by study of the total number of pc and pt, but by study of cases of pulsations with respect to intensity of the amplitude (A + B).

Brief conclusions.

Results of the comparisons of data obtained at the four middle-latitude stations permit us to make the following conclusions as to the character of the SPP excitation of the earth's electromagnetic field in the middle latitudes.

1. The SPP are characterized by two essentially different regimes: continuous pulsations pc, with periods of 15-40 seconds, and train-type pulsations pt, with periods of 50-90 seconds.

2. These two regimes develop in such a manner, in relation to local time, that the maximum of pc occurs at the local midday, and the maximum of pt at local midnight.

3. The growth of excitation of pc occurs approximately 1.5 times

faster than their attenuation.

4. The seasonal distribution of pc and pt is expressed unclearly; this is apparently normal for the middle latitudes. However, one can speak of a tendency towards an increase in the amount of pc in the summer and towards a decrease in winter. No tendency whatsoever is observable for pt.

5. The amplitudes of SPP in the middle latitudes, in general, are not large and for pc amount to fractional-unit and unit millivolts per kilometer, while for pt, they amount to 1-10 millivolts per kilometer. A tendency is noted for an increase in the amplitudes for coastal stations.

In conclusion, we should dwell on a number of problems, the necessity for the study of which developed in the process of the primary processing of the materials.

A large number of observations indicates that the structure of the pc and pt regimes is complex. In addition to the undoubted dependence of SPP excitations on local time, control by universal time also exists. During the initial processing of the data and plotting of the respective graphs, no cases of this nature were isolated. This led, on one hand, to a less clear determination of the relationship of the processes of SPP excitation to the local time, and on the other, did not permit us to study the degree of the effect of universal time on these processes.

In the further study of SPP, a detailed classification of the pulsations should be made and groups with principal subordination to universal and to local time should be isolated. The analysis of these groups, which possibly differ in origin, should finally resolve the question as to the time control factor of SPP.

To test the conclusions and hypotheses made in this article, analogous research must be carried out at other middle-latitude stations of the IGY, in particular at stations located in the western hemisphere. A thorough frequency-amplitude analysis of the two SPP regimes with the determination of a relationship between the excitation of pulsations at various periods and amplitudes and the time of day could be of great interest.

It is not to be doubted that reliable conclusions as to the nature of SPP and other problems in the study of the field of the earth's currents can be made only jointly with the research on other phenomena of the electromagnetic complex.

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IV. SHORT-PERIOD PULSATIONS OF THE ELECTROTELLURIC FIELD (According to the Observation Periods in Irkutsk)

by

P. A. Vinogradov

The study of short-period pulsations (SPP) is based mainly on observations made at the stations of Bayanday (Ref. 1) from September 1957 to August 1959 and Uzur (Ref. 2) from September 1958 to October 1959.

The quality of the recordings at the Uzur station permit us confidently and reliably to divide the SPP into pc and pt classes (Ref. 3) and to find their parameters; diurnal periods with SPP and without them can be clearly seen on the recordings (Fig. 1). Numerous disturbances in the region of the Bayanday station considerably complicated the interpretation of the recordings. The profiles of the disturbances frequently suggesting pt-class pulsations.[1] Therefore in some cases the accurate determination of pt can be made only after comparison with the data of some other station. The data supplied by Committee No. 10 of the International Association of Geomagnetism and Aeronomy were used for this purpose (Ref. 4).

According to the recordings made at Bayanday and Shamanka, the pc-type pulsations were divided into 3 groups: A—clearly expressed pulsations (amplitude more than 5.4 mv/km); B—normal, but accurately determinable pulsations (amplitude 1.6-5.4 mv/km), and C—doubtful cases (amplitude less than 1.6 mv/km).

Continuous Pulsations, pc.

The diurnal distribution of pc—S(pc). According to observations at Bayanday, S(pc) has the shape of a simple wave with one maximum and one minimum. The maximum of S(pc) occurs at the midday hours with a center at 1000-1100 hours local time (0300-0400 hours universal time), and the minimum during the night hours with the center at 2300-0100 hours local time (1600-1800 hours universal time).

A similarity is observable in the shape of S(pc) for the various seasons and years. A general characteristic of all seasons

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1 In connection with this, at the end of February, 1959, observations were transferred to Shamanka (15 kilometers from Bayanday).

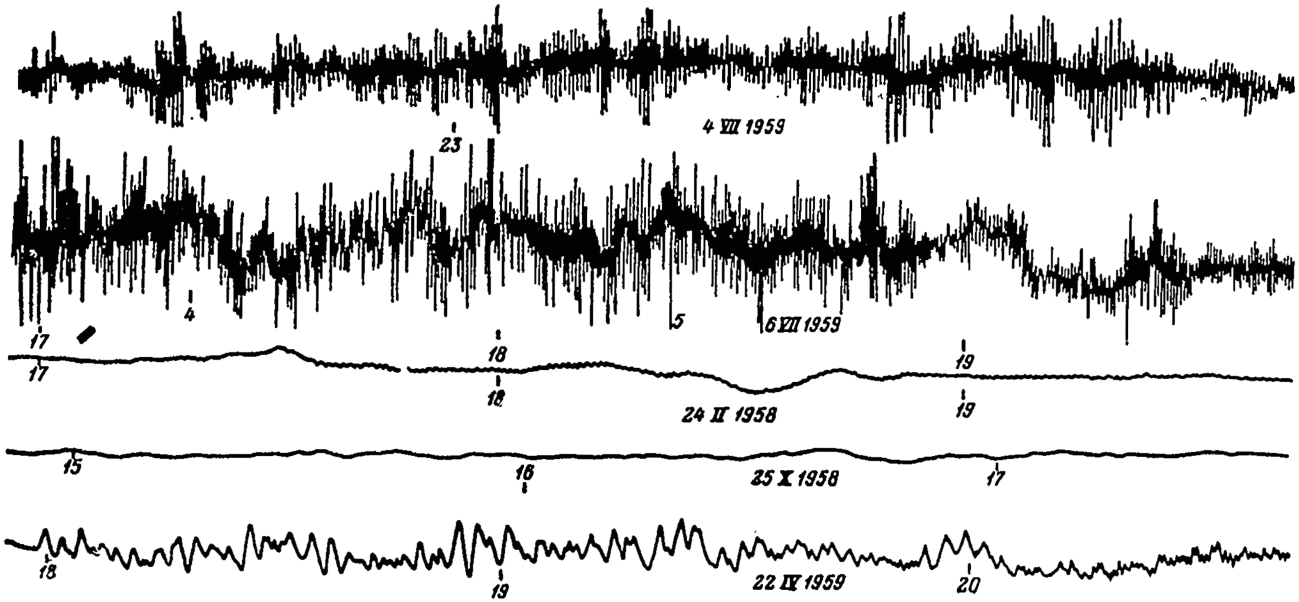

Fig. 1. Examples of recordings of variations of the eastern portion of the earth's current field at the Uzur station.
Universal time. Upper two recordings-pc; lower recording-pulsation of a large period; middle recordings-very weak pc (24 February 1959) and their complete absence (25 October 1958). Sensitivity of the registration was 1.2 x 0.11 mv/km x mm.

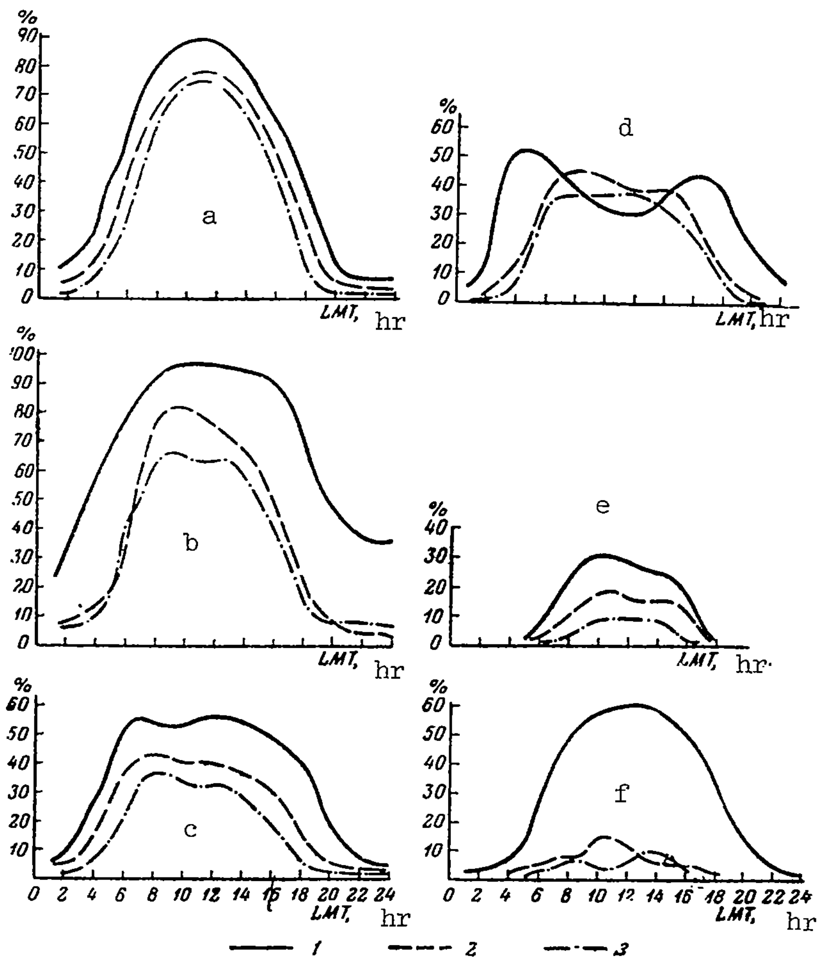

Fig. 2. Distribution of pc according to hours of local time at Bayanday.
a-all pc for November 1957-August 1958; b-all pc for September 1958-August 1959; c-pc with an amplitude from 1.6 to 5.4 mv/km for September 1957-August 1958; d-pc with an amplitude from 1.6 to 5.4 mv/km for September 1958-August 1959; e-pc with an amplitude exceeding 5.4 mv/km for September 1957-August 1958; f-pc with an amplitude exceeding 5.4 mv/km for September 1958-August 1959; 1-summer; 2-equinox; 3-winter.

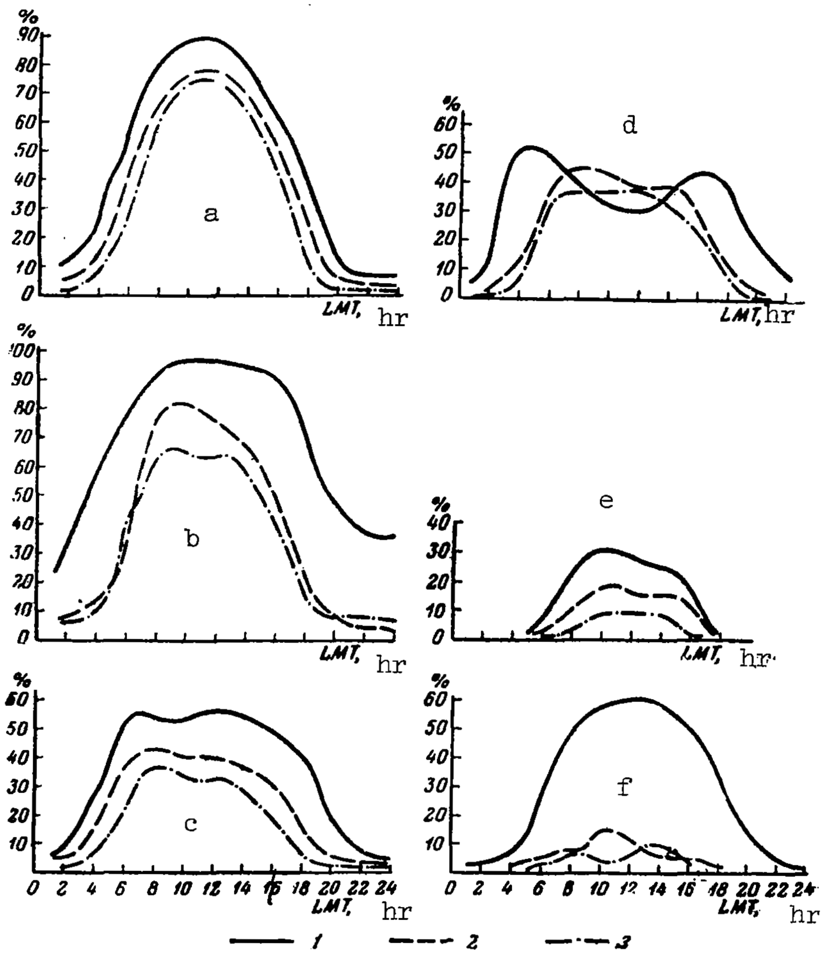

Fig. 2. Distribution of pc according to hours of local time at Bayanday.
a-all pc for November 1957-August 1958; b-all pc for September 1958-August 1959; c-pc with an amplitude from 1.6 to 5.4 mv/km for September 1957-August 1958; d-pc with an amplitude from 1.6 to 5.4 mv/km for September 1958-August 1959; e-pc with an amplitude exceeding 5.4 mv/km for September 1957-August 1958; f-pc with an amplitude exceeding 5.4 mv/km for September 1958-August 1959; 1-summer; 2-equinox; 3-winter.

is the asymmetry of these distributions in relation to noon. The degree of asymmetry from season to season changes little, but some decrease of it is observed in the summer. Extremal values of S(pc) undergo marked changes in the course of a year, an increase in the maximum being accompanied by an increase in the minimum but not in equal measure. Owing to this a change also occurs in the amplitude of S(pc); there is disclosed a considerable predominance of the maximum of S(pc) in summer, both in the first and second year of observations (95.5 and 94.2 percent respectively), over the maximum observed in winter (75.2 and 63.5 percent); the maximum of S(pc) during the equinoxes is 10 percent lower than the maximum observable in summer.

The size of the interval favorable for the appearance of pc increases from winter to summer. According to the results of the first year of measurements, these pulsations were noted in winter principally in the interval from 0500 to 1800 hours, and in summer from 0200 to 2000 hours. The period favoring the appearance of pc in the summer of 1959 increased still more considerably. Its spread to earlier and later hours of local time, and the considerable increase in the number of hours with pc, may indicate a certain relationship between the appearance of pc and solar wave radiation.

The time of the maximum of S(pc) is more stable than the time of the minimum.

It is interesting to examine separately the diurnal distribution of pc of various intensities (Fig. 2). Characteristic of the diurnal distribution of pulsations with the greatest intensity S(pcA) is their complete absence in the night hours (with the exception of the summer 1959) and the localization of the interval of their occurrence around local midday. The limits of the interval of excitation of pcA vary both with respect to season and from year to year. Whereas, for example, in the winter 1954-1958 pc A were observed principally in the period from 0800 to 1500 hours local time, and in the summer of 1958 from 0500 to 1700 hours, in the summer of 1959 the period favorable for the appearance of pcA was the period from 0200 to 2000 hours local time. The maximum of the frequency of appearance of pc A was observed during 0800-1100 hours local time. The maximal frequency of the appearance of these pulsations is observed in summer.

In distinction from S(pc) and S(pcA), the maximum of S(pcB) is very wide, and in the summer of 1959 it even had the shape of a double wave. The appearance of these peculiarities of S(pcB) is connected with the diurnal change in the intensity of the continuous pulsations. Not only may the curves of S(pcB) be interpreted as curves illustrating the diurnal distribution of the number of pulsations of a definite amplitude, but also as curves characterizing the pattern of

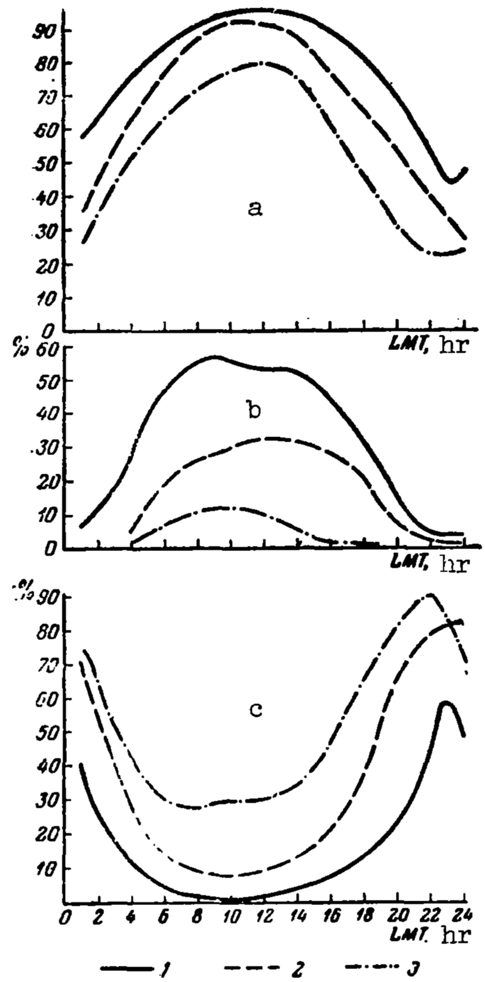

Fig. 3. Distribution of pc according to hours of local time at Uzur.
a-all pc; b-pc with an amplitude exceeding 1 mv/km; c-pc with an amplitude of 0.18 mv/km; 1-summer; 2-equinox; 3-winter.

the diurnal change of intensity of pc. Looking at S(pc A) and S(pc B), we see that a more rapid growth of intensity of the continuous pulsations from the night hours to the day hours is observed in the summer, when a considerable number of pc (as the intensity increases) already at 0400 hours passes from group B to group A, whereas in winter such a transition begins mainly at 0800 hours local time.

Just as at the Bayanday station, the greatest frequency of occurrence pc at the Uzur station is observed at 1000-1300 hours local time (Fig. 3). The S(pc) at the Uzur station is not symmetrical relative to the local midday, the degree of asymmetry decreases from winter to summer.

The duration of the maximum of S(pc) increases from winter to summer, but the center of the maximum is observed mainly in the interval of 1000-1100 hours local time. Comparing the frequency of occurrence of continuous pulsations at moments of the extremes of S(pc) in Uzur and Bayanday, we observe a significant increase of the frequency of occurrence of pc at the midnight hours in Uzur with a comparatively weak increase of repeatability during the midday hours. As a result a more equal distribution of pc takes place in Uzur over all the hours of the day.

The diurnal distribution of weak pc (with an amplitude less than 0.18 mv/km) is represented by a simple wave with a maximum during the night hours (2100-2400 hours) and the minimum in the day hours (0800-1100 hours) local time. As a result of such an uneven distribution of weak pulsations in the hours of the day, the shape of S(pc) depends on the sensitivity of the recorder.

Comparing the diurnal distribution of the intensive pc in Bayanday and in Uzur, we find that there is no substantial difference between them.

Relationship of pc to the activity of the geomagnetic field. With an increase in the activity of the geomagnetic field, the frequency of appearance of pc increases: whereas the average occurrence of pc for days with 0 magnetic characteristic amounts to 27.4 percent, for days with a 2 characteristic it amounts to 62.8 percent. With an increase in the magnetic activity the duration, in days, of the period favorable for the appearance of pc (Fig. 4) also increases. Regular change of the asymmetry of S(pc) in relation to the degree of geomagnetic activity is not observed. For example, the ratio of the number of hours with pc in the first half of day to the number of hours with pc in the second half of day with 0 and 2 characteristics is the same and is equal to 1.4 : 1. The moments of the maxima of S(pc) do not depend on the degree of activity of the geomagnetic field.

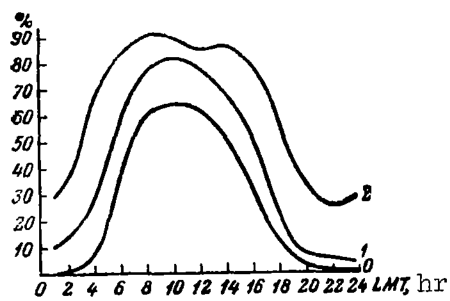

Fig. 4. Distribution of pc according to hours of local time during the days of varying magnetic activity (0,1,2).

The distribution of pc according to periods indicates that SPP with 20-25 sec periods are encountered most frequently (Fig. 5a), periods from 15-30 sec are encountered with sufficient frequency, and pulsations with periods more than 40 sec are significantly rarer (pulsations with periods of less than 8 sec were examined separately, and these data are not presented here).

The distribution curves of pc according to periods for the intervals from 0600 and 1200 and from 1200 and 1800 hours local time differ from one another very insignificantly (Fig. 5b). On disturbed days pulsations with periods of 10-16 sec are the most frequent, while on quiet days—pulsations with periods of 20-30 sec are the most frequent. Comparing the distribution curves of pc by periods in Irkutsk and in Aleksandrovsk-na-Sakhaline (Fig. 5c, d), we find an almost complete coincidence of the curves for disturbed days and a certain difference of the curves for quiet days, which, apparently, was caused by the fact that the materials employed did coincide according to the time of observations. Comparison of the pc distribution by periods for shorter intervals of time has shown that the pulsations observed simultaneously in Aleksandrovsk-na-Sakhaline and in Irkutsk coincide well with respect to frequency.

Amplitude characteristics of pc. The amplitude of continuous pulsations is at a maximum at the midday hours, local time, and is at a minimum in the night hours; the change of amplitudes occurs gradually (Table 1). The change curve according to hours of the day of the average-hourly amplitudes of pc, similar to the curve for S(pc), has the appearance of a simple wave with a maximum at the midday hours (1100-1200) and a minimum at the midnight (2300-2400) hours, local time.

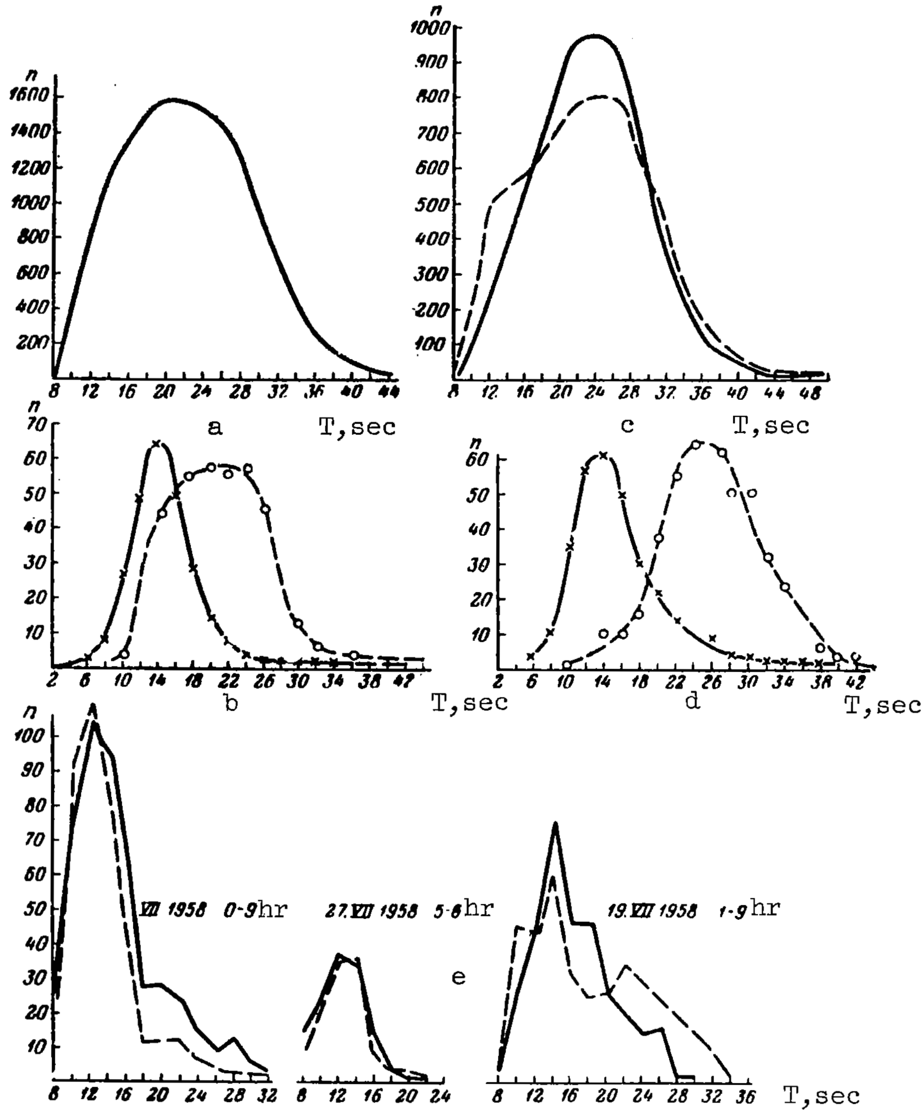

Fig. 5. Distribution of pc according to periods. a-general distribution; b-distribution in the 0600-1200 hours interval (solid line) and from 1200 to 1800 hours (broken line) of the local time; c,d-distribution on the days of various magnetic activity; on international quiet days (broken line) and on international disturbed days (solid line); according to observations at Aleksandrovsk-na-Sakhaline (c) and in Irkutsk (d); e-according to simultaneous observations in Irkutsk (broken line) and in Aleksandrovsk-na-Sakhaline (solid line) for short intervals. The data were obtained on the basis of recordings with a rotation of 30 mm/min.

The shape of the curve of the diurnal change of the average-hourly amplitudes of pc changes little with the times of the year. The most intensive pulsations appear during the course of the entire year in the interval of 0900-1200 hours, local time, but the interval of occurrence of intensive pc is more lengthy in summer (0600-1500 hours) than in winter (0800-1200) or in the equinoxes (0700-1400 hours).

A close correlation is observed between the diurnal distribution and the diurnal changes of the average-hourly amplitudes of pc (Fig. 6).

Seasonal course of pc. The noticeable increase in the number of hours with pc from winter to summer attracts attention (Fig. 7). Thus in 1958 the least number of hours with pc was observed in November (about 20 percent) while the greatest number of hours was in June (54.6 percent). An analogous increase in the number of hours with pc from winter to summer was observed in 1959: the least number was in January (22.4 percent) and the greatest in June (77.5 percent).

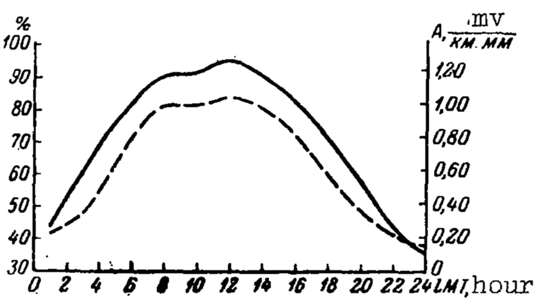

Fig. 6. Correlation between the diurnal distribution of continuous pulsations (solid line) and the diurnal changes of amplitude (broken line).

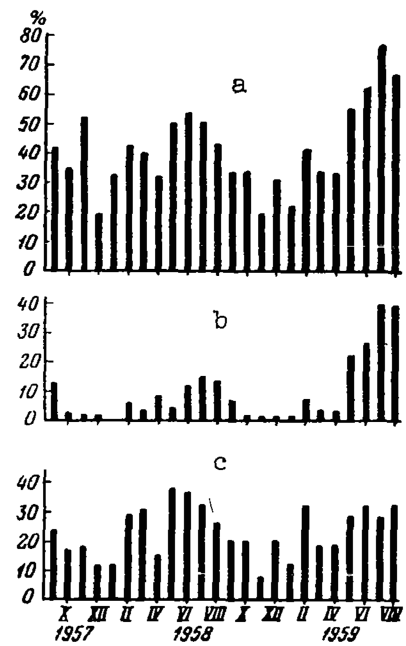

Fig. 7. Distribution of pc by months.
a-all pc; b-pc with an amplitude exceeding 5.4 mv/km; c-pc with an amplitude from 1.6 to 5.4 mv/km.

In addition to the increase in the frequency of appearance of pc from winter to summer, a marked rise in their intensity is noted: the average amplitude of pc in winter is equal to 0.29 mv/km, and in summer to 1.09 mv/km (Table 1). A rise of pc in the summer months can also be seen from the increase of the number of intense pulsations from winter to summer: pulsations with an amplitude exceeding 5.4 mv/km amounted in winter to only 2.6 percent of the entire number of pc, while in summer these pulsations amounted to 29.6 percent.

Analogous results for the distribution of the frequency of appearance and intensity of pc by seasons of the year have been obtained from the data of observations at Uzur (Table 2). Comparison of the yearly changes of the average-monthly amplitudes of pc with the yearly distribution of the frequency of their appearance shows a close correlation between these values: they have the shape of a simple wave with a minimum in December and a maximum in July. A certain parallelism is observable in the yearly change in the K-and S-characteristics of magnetic activity and the frequency of occurrence of pc.

Pulsations Trains, pt.

Diurnal course of pt. Whereas the regularity of their disturbance from day to day is characteristic for pc pulsations, for pt pulsations this regularity is not observable.

During the year of observation at Uzur, the number of days with pt amounted to 38 percent while the number of hours with these pulsations (according to the ratio of the number of hours of observations) amounted only to around 3 percent. During this same period the number of days with pc amounted to 93.7 percent, while the number of hours with pc was 71.1 percent.

S(pt) has the shape of a simple wave with the largest number of appearances of pulsations in the midnight hours and the least number at the midday hours, local time (Table 3). In the course of the entire year pt are observed mostly from 2200 to 0200 hours, local time, and from 0700 to 1500 hours they are, as a rule, encountered very rarely. The number of cases of pt is somewhat larger in the interval from 1200 to 2400 hours than from 0000 to 1800 hours. Asymmetry of S(pt) is observed in all the seasons of the year, and from year to year.

Frequently during the evening and night hours pulsations are observed which approach pt according to period, but do not have a dampening pulsating condition characteristic for them. The diurnal distribution of such pulsations with a large period PLP is analogous

Hours of the day	1	2	3	4	5	6	7	8	9	10	11	12	13
Winter	0,17	0,21	0,18	0,27	0,34	0,39	0,39	0,37	0,47	0,48	0,48	0,48	0,41
Summer	0,37	0,47	0,54	0,49	1,01	1,24	1,70	1,77	1,78	1,68	1,76	1,97	1,68
Equinoxes	0,17	0,23	0,29	0,42	0,62	0,67	0,75	0,91	0,87	0,94	1,05	1,28	0,98

Hours of the day	14	15	16	17	18	19	20	21	22	23	24
Winter	0,39	0,32	0,32	0,25	0,22	0,20	0,19	0,18	0,16	0,17	0,18
Summer	1,80	1,75	1,37	1,15	0,90	0,72	0,59	0,46	0,39	0,24	0,26
Equinoxes	0,89	0,84	0,78	0,72	0,45	0,51	0,32	0,21	0,15	0,21	0,15

Table I

Changes of the Average Hourly Amplitudes of pc (in mv/km) According to Hours of the Day on the Basis of Observations at Uzur.

Months	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
All pc, %	57,7	64,4	74,7	73,7	82,4	84,0	86,8	78,9	72,6	68,8	53,8	54,4
pc with an amplitude in excess of 1 mv/km	4,1	6,9	14,2	21,5	34,2	36,4	37,5	30,2	25,3	6,5	3,4	4,3
Average amplitude for the month	0,29	0,32	0,47	0,54	0,83	0,90	1,52	1,14	0,94	0,40	0,30	0,29

Table II

Distribution of pc by Months According to Observations in Uzur.

Hours of the day		1	2	3	4	5	6	7	8	9	10	11	12	13
Bayanday	Winter	18	17	8	4	4	1	1	—	—	—	1	1	—
	Summer	18	19	11	6	3	1	1	—	—	—	1	—	1
	Equinox	25	12	15	8	5	4	3	—	—	—	—	—	—
Uzur	Year average	35	24	17	10	3	1	1	1	—	—	—	—	—
	Amplitude	3,44	2,91	3,02	2,97	2,69	1,80	2,70	2,38	—	—	—	—	—
	PLP	25	20	14	13	7	3	—	—	—	—	—	—	—

Hours of the day		14	15	16	17	18	19	20	21	22	23	24
Bayanday	Winter	1	1	1	1	1	2	6	14	18	19	18
	Summer	—	1	—	1	2	6	7	8	18	20	20
	Equinox	1	1	—	1	2	3	5	12	16	26	22
Uzur	Year average	—	—	1	1	2	6	8	21	24	31	30
	Amplitude	—	—	1,70	1,65	2,58	2,68	3,11	2,81	3,08	3,04	3,08
	PLP	—	1	1	1	1	2	8	10	17	22	28

Table III

Distribution of S(pc) by Hours, Local Time.

Time of Year	Magnetic characteristics of the day		
	0.5	1.0-1.5	2.0-2.5
Winter	2.97	4.84	4.42
Summer	2.02	2.50	2.22
Equinox	2.77	4.11	3.84

Table IV*

Number of Hours with pt (in % of Total Number of Hours of Observations).

* Compiled on the basis of observations made in 1952-1955.

Months		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Uzur	No. of cases of pt	21	18	15	25	12	28	17	18	18	14	14	16
	Average amplitude of pt, mv/km	4,22	3,41	1,64	2,80	3,25	2,51	2,69	2,77	2,70	2,50	3,02	3,75
	PLP	16	15	11	9	17	11	9	19	18	20	17	13
Bayanday, average for 1957-1959		20	15	18	14	17	13	18	14	16	19	14	18

Table V

Distribution of pt by Months of the Year.

to the diurnal distribution of pt (Table 3). The yearly distribution of pt and PLP also coincides. Thus one can suppose that the nature of pt and PLP, apparently, are one and the same.

The most intensive pt are observed during the night hours. There is a parallelism between the diurnal distribution of pt and the diurnal change of the amplitudes (just as for pc).

Relationship of pt with the magnetic activity and the seasonal variation of pt.

The peculiarity of S(pt) noted above, a clearly expressed simple diurnal wave with the most frequent appearance of pt during the midnight hours, is repeated without substantial changes in the various seasons and on the days of various magnetic activity. During all the seasons of the year the number of cases of the appearance of pt (Table 4) increases with an increase in the magnetic activity, but their maximum repeatability is observed not on the days of the greatest magnetic activity (with diurnal characteristics of 2.0 and 2.5) but on days of average activity (with characteristics of 2.1 and 1.5).

No definite relationship of the frequency appearance of pt to the seasons of the year was observed. At the same time it can be seen from Table 4 that pt are encountered more frequently in winter than in summer. An analogous pattern of the yearly change of pt can be obtained from Table 5 if the yearly changes of pt and the PLP are examined together. The amplitude of pt is noticeably greater in winter months than in the summer and the equinoxes.

Distribution of pc and pt according to local and universal time.

In Fig. 8 are presented the distribution curves of pc and pt, according to the hours of local and universal time, obtained from the material of preliminary data reported by Committee 10 of the International Association of Geomagnetism and Aeronomy. A comparison of the S(pc) of three eastern stations (Mombetsu—$43^{\circ}55'$ N, $144^{\circ}12'$ E, Kanoya—$31^{\circ}25'$ N, $130^{\circ}53'$ E, and Irkutsk) indicates that the curves of S(pc) for universal and for local time are almost indistinguishable from one another. From the tables of the average diurnal distribution of pc for the year, we find the largest number of appearances of pc is observed in Mombetsu from 2300 to 0200 hours, in Kanoya from 2200 to 0300 hours and in Irkutsk from 0100 to 0400 hours, universal time.

Considering the horizontal character of the maximum of S(pc) and the limited nature of the material used (only for 1958), it is

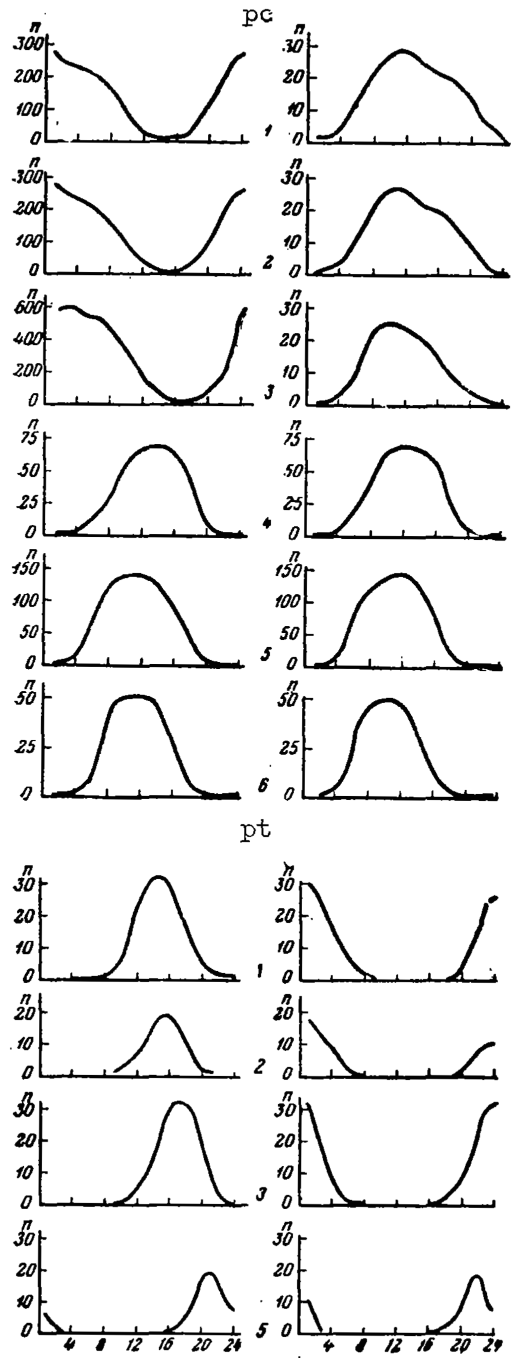

Fig. 8. Diurnal Distribution of pc and pt at various stations. 1-Mombetsu; 2-Kanoya; 3-Irkutsk (Bayanday); 4-Hartland; 5-Budkov; 6-Valencia.

apparently impossible to conclude from the data that the maximum of S(pc) is observed according to local time and not at the same time at all three stations. In addition to this, comparison of the pc in Irkutsk and Aleksandrovsk-na-Sakhaline (according to simultaneously registered data over a period of 4 months) showed a synchronous change of the regime of continuous pulsations at these points.

Comparison of the S(pc) of one of the western stations (Budkov—$49^{\circ}04'$ N, $14^{\circ}01'$ E, Hartland—51° N, $04^{\circ}29'$ W, and Valencia—$51^{\circ}56'$ N, $10^{\circ}15'$ W) also indicates a somewhat different character of the curves of S(pc) plotted according to universal and local time, and does not solve the problem as to whether the diurnal curves of S(pc) proceed according to local or universal time.

However, the simultaneous examination of the data of all six stations leaves no doubt that a single S(pc) for all six stations can be obtained only according to the local time.

Upon examining the distribution of pc according to hours of the universal time, it can be seen that the moments of the minimum of S(pc) of stations of the eastern group differ little from the moments of the maxima of stations of the western group. Therefore it may be assumed that the S(pc) of two stations differing by 180 degrees in longitude must occur on counterphase. Thus it is possible to say (considering the above-mentioned parallelism between S(pc) and the diurnal changes of the intensity of pc) that at any given moment the most intensive pc are observable on the day side while the weakest pc are observable on the night side.

On the days of intensive development of continuous pulsations, pc can be observed simultaneously over the entire earth since, as was stated above, the duration of the disturbance interval of pc is in a direct dependence to their intensity.

The curves of S(pt) of the eastern group of stations are sufficiently reliable. In view of the limited nature of the data from the western group of stations, S(pt) was presented only for one station (Budkov). The curves of the eastern stations differ little from one another; the moments of the extremes at Mombetsu and Kanoya coincide. Common to all the eastern stations is the coincidence of the time of the maximum of S(pt) with the time of the minimum of S(pc), i.e., these curves are in counterphase.

Thus the development of short-period pulsations of the pc class proceeds according to local time. The greatest development of pc on the day side and weakness (sometimes complete absence) on the night side of the earth is characteristic of the planetary distribution of pc. For pulsations of the pt class, conversely, maximum development and greatest frequency of appearance on the night side of the earth are characteristic.

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V. RAPID GEOELECTRICAL AND GEOMAGNETIC VARIATIONS AND THEIR REGULARITIES (According to Observations in Ashkhabad)

by V. G. Dubrovskiy

Regularities of the excitation of rapid geoelectrical and geomagnetic variations were studied by us on the basis of recordings of earth currents from January 1956 through December 1958, and on the basis of magnetograms from April through December 1958. These recordings were obtained at the Geophysical Station of the Institute of Physics and Geophysics of the Academy of Sciences Turkmen SSR (21 kilometers west of Ashkhabad). The geomagentic coordinates of the station are as follows:

$\Phi = 30^\circ 20'23''$ N and $\Lambda = 133^\circ 04'20''$.

The earth-current installation has two receiving pairs of electrodes with a base distance of 0.37 kilometers oriented in north-south and east-west directions, and connected with the registering apparatus by underground lines.. The recording is carried out at a rotation speed of 90 mm/hour (the division values were of the order: NS 0.4-0.6 mv/mm·km; EW 0.8-1.3 mv/mm·km and 30 mm/minute) (Ref. 1).

Recording at the speed of 30 mm/minute was done with the aid of capacitive coupling of the electrodes (80 μ f) and galvanometers with a period of proper pulsations of 0.75 seconds and a constant with respect to current of 10-9 amp/mm·m. The greatest sensitivity here (the division value of the two components is 0.05 mv/mm·km) occurs at a period of 2 seconds.

Registration of the geomagnetic variations was done at a rotation speed of 90 mm/hour with the aid of a magnetograph with a rapid register which had been modernized by us. Recording is carried on continuously for 12 hours on light-sensitive tape measuring 30·150 cm, without any lateral shift of the register drum, as is the case with the Lakur register. This was achieved by a fourfold decrease (from 360 to 90 mm/hour) of the line as rotation rate of the main drum, and the use of an auxiliary receiving drum on which the light-sensitive tape is wound.

The division values and the dynamic parameters of the variometers are presented in the table.

Components	Period T, sec	Attenuation, D
H 0.9-1.1	6.8	0.1
D 0.9-1.1	3.7	0.05
Z 0.9-1.1	2.0	0.6-0.7

TABLE

The classification of short-period variations adopted at the conference of Committee No. 10 on Rapid Variations of the Geomagnetic Field and Earth Currents, held in Copenhagen (9-11 April 1957), was made the basis of the method for processing the observation results.

Of the various forms of rapid geomagnetic and geoelectrical variations, the following were examined by us:

(1) short-period pulsations with a continuous (pc) and a noncontinuous (pt) regime, which in turn were divided according to the character of the pulsations into regular (pc_R, pt_R) and irregular (pc_i, pt_i);

(2) short-period pulsations of the beat type (pp)--pearls;

(3) sudden commencements of magnetic and geoelectrical disturbances (ssc);

(4) bay-shaped geoelectrical and geomagnetic disturbances (b).

Investigated in course of the analysis were the diurnal and seasonal regularities (in the presence of sufficient observation material), the distribution according to periods, the existence of accompanying phenomena, and connection with other geophysical phenomena, in particular with the level of geomagnetic activity and polar aurorae.

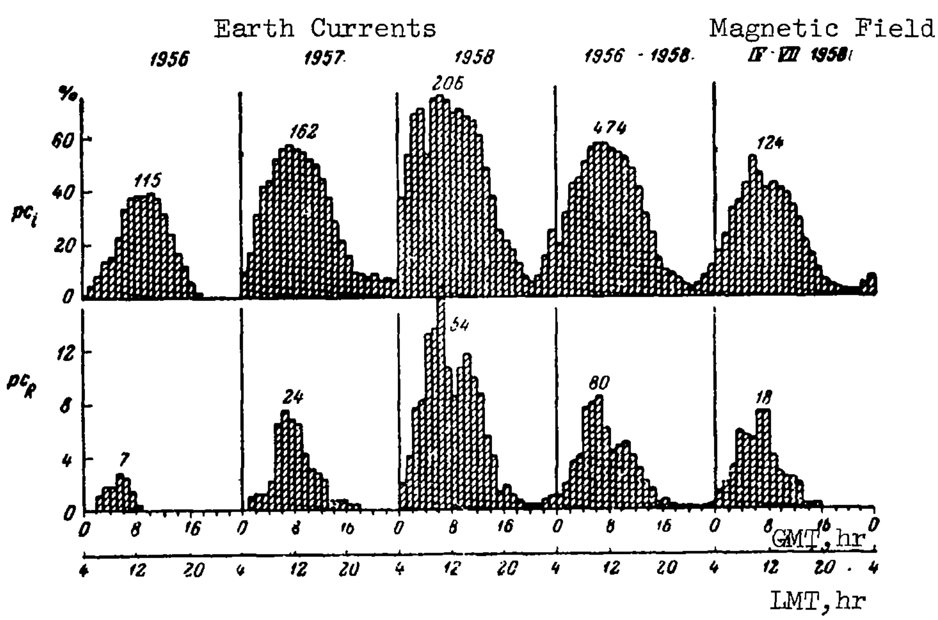

Figure 1. Diurnal distribution of the probability of appearance (along the vertical axis, per cent) of continuous SPP of the earth currents and the geomagnetic field.

Short-Period Pulsations of the pc_i and pc_R Types

The diurnal distribution of the probability of appearance of short-period pulsations of earth currents and of the geomagnetic field of the pc_i and pc_R types are presented in Figure 1. From the graphs it can be seen that the diurnal regularities plotted separately for 1956, 1957, and 1958 essentially repeat one another. The growth of the maxima of the short-period pulsations of earth currents in the transition from 1956 to 1958 can apparently be explained by the increase of solar activity during these years. The greatest probability for the appearance of pc_i comes during the daylight hours with a maximum (55 per cent) at the local midday (0800 hours GMT) and the minimum (4 per cent) at midnight (2000 hours GMT).

The diurnal variation of regularly shaped pulsations of the pc_R type has the same character. The distribution of the same types of pulsation of the geomagnetic field is absolutely analogous to the diurnal variation of the geoelectrical pulsations.

The dependence of the probability of appearance of the short-period pulsations of earth currents on season is shown in Figure 2. From the graphs it can be seen, in the first place, that the qualitative character of the diurnal course of pc_i and pc_R pulsations does not vary with respect to the season of the year, and second, that the maximum value of the probability of excitation in summer is approximately 1.5-2.0 times greater than in winter.

In order to determine the possibility of a dependence of the frequency of appearance of continuous pulsations of the pc_i and pc_R types on the degree of disturbance of the geomagnetic field, we examined the diurnal distribution of the probability of their excitation (Figure 2) for two degrees of geomagnetic activity. From the graph it can be seen that the maximum probability; the appearance of pc pulsations on magnetically disturbed days is 10 per cent higher than on quiet days. But although it is difficult to distinguish short-period pulsations against a background of strongly disturbed recording, it may be expected that the probability of their excitation is greater.

Let us examine the frequency spectrum of the distribution of short-period pulsations. In the graph presented in Figure 3, five-second intervals of the pulsation periods are plotted on the abscissa, and the probability of appearance of the pulsations in each interval,

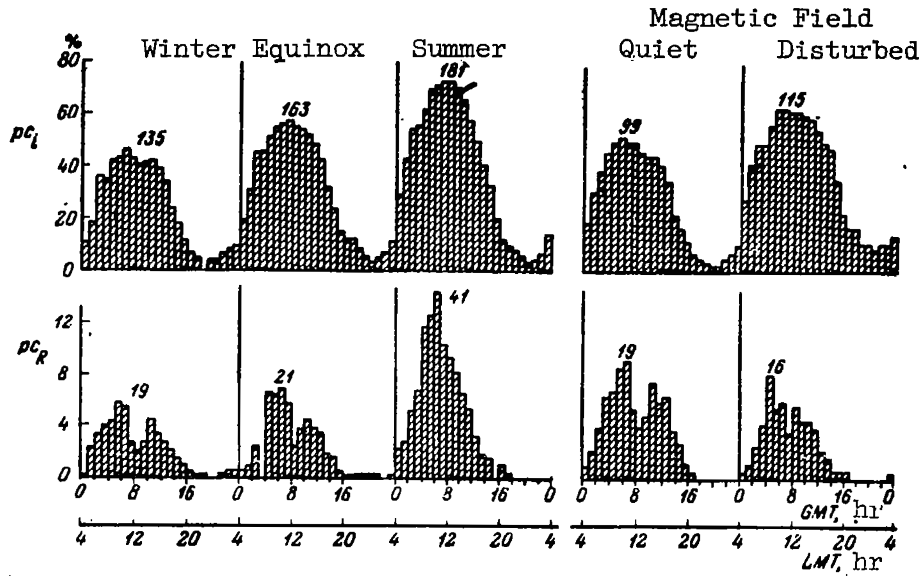

Figure 2. Dependence of the probability of appearance of continuous SPP of earth currents on the season.

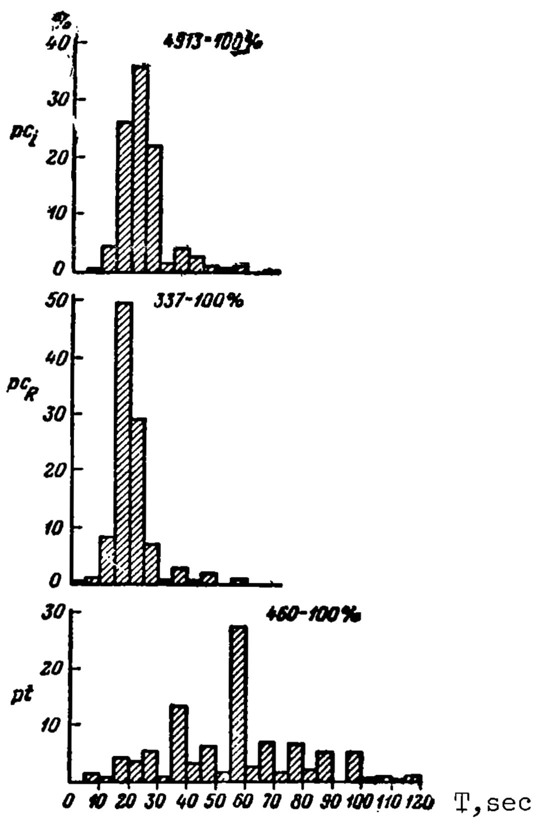

Figure 3. Probability of appearance of pc and pt of various periods.

in per cent, is plotted on the ordinate axis. The greatest probability of the excitation of short-period pulsations of the pc_i type occurs at 20-25 second interval, and that of the pc_R type pulsations at 15-20 seconds.

Short-Period Pulsations of the pt Type

The regularities of the diurnal distribution of short-period pulsations with non-continuous regimes of the pt type are presented in

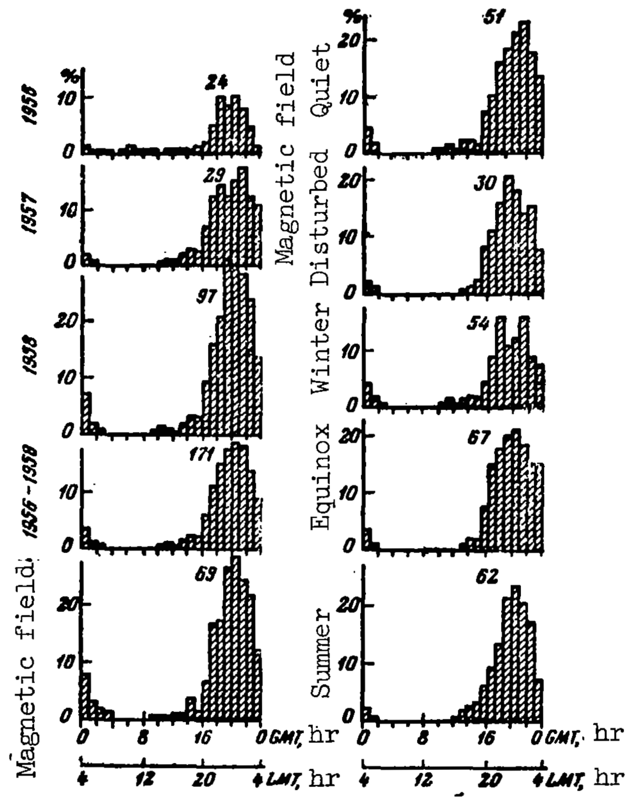

Figure 4. Yearly (a) and seasonal (b) relationships of the diurnal distribution of pulsation trains pt.

Figure 4. From the graph it can be seen that pulsations of this kind are excited principally in the night hours, with a maximum (18 per cent) at local midnight (2000 hours GMT). Their diurnal variations plotted separately for 1956, 1957, and 1958 are similar to one another, and the probability of their excitations is highest of all in 1958 just as it is for pulsations of the pc_i and pc_R types. The seasonal dependence of the

appearance of pulsation trains pt is also similar to that of pulsations of the continuous type: the probability of their excitation is highest in summer and lowest in winter.

With an increase in the level of geomagnetic activity, the probability of pt excitation is practically unchanged (Figure 4). The most characteristic period of pt is 55-60 seconds (Figure 3).

Thus, in general the results obtained by us agree well with the known data; nevertheless certain peculiarities may be noted. In particular, the maximum probability of the excitation of pc and pt occurs at local midday and local midnight respectively; this can indicate excitations of the short-period pulsations according to local time. Furthermore, the probability of the appearance both of continuous pulsations and pulsation trains is greatest in the summer time and lowest in the winter.

Rapid Variations of the Types pp, b and ssc

Among the other types of rapid variations of the earth's electromagnetic field, attention must be paid to the uniquely constituted short-period pulsations of the "beat" type, designated by pp and characterized by a small period (1-3 seconds) and a regular sinusoidal shape, "pearls".

From July 1957 through March 1959, pp-type pulsations were registered 66 times in Ashkhabad, 60 of them being observed during geomagnetic and geoelectrical storms. This latter fact indicates that these pulsations are a constituent element of the complex micro-structure of the disturbances of the earth-current field. Below is presented the distribution of the number of cases of the registration of pp in relation to the pulsation period. We see that most of the pulsations encountered have a period of from 1 to 2 seconds.

Period, seconds	0.5-1.0	1.1-1.5	1.6-2.0	2.1-2.5	2.6-3.0	3.1-3.5	3.0-4.0	4-4.5
No. of Cases	7	14	25	4	0	1	1	0

The diurnal distribution of pulsating of the "beat" type, (pp) presented in Figure 5 (left graph), is characterized by the largest frequency of their appearance during the night hours with the maximum occurring around midnight in local time. The right-hand portion of Figure 5 shows the diurnal distribution of bay-shaped disturbances (b) of the geoelectrical field for the same period of observation.

The similarity in the regularities of the diurnal distribution of bay-shaped disturbances and short-period pulsations of the "beat" type compels us to suppose a connection between them. However, direct comparison of these types of rapid variation indicates that out of 42 bay-shaped disturbances only 3 were accompanied by pulsating-type pulsations. At the same time, in 27 cases train-type pulsations were observed. Thus it is apparent that bay-shaped disturbances of the geoelectrical field are not connected with pp-type pulsations but are correlated with train-type pulsations.

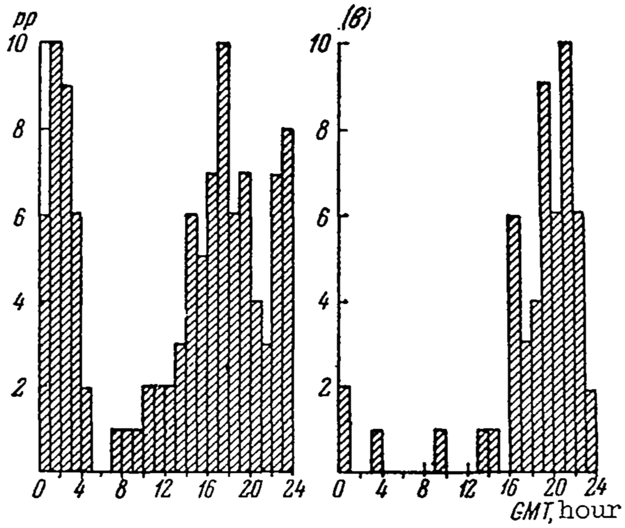

Figure 5. Diurnal distribution of "beat"-type pulsations (pp) and bays (b) for July 1957-December 1958.

The amplitudes of SPP of the pulsating type registered in Ashkhabad normally have values of 0.3-0.6 mv/km. However in a number of cases, for example on 4, 13, 29 September 1957, 11 February, 6 June and 4 September 1958, the "beat"-type pulsations had amplitudes exceeding 1-5 mv/km. In each case the pulsations were observed against a background of large geomagnetic and geoelectrical disturbances, which as a rule had sudden commencements. Intensive "beat"-type pulsations--gigantic pulses --in Ashkhabad coincided in time with instrumentally recorded polar aurorae.

From July 1957 through March 1959, 77 cases of rapid variations of the ssc and ssc* types were registered in Ashkhabad. As a rule, these variations are observable simultaneously in the recordings of earth currents and the geomagnetic field, in the predominant number of cases the symbols for the variations in the magnetograms being as follows: H_+, D_-, Z_- for ssc and H_+, D_{++}, Z_- for ssc*. Both in this case and in the case of bay-shaped disturbances, the earth-current vector is rather strictly polarized in a NS direction, at an angle of 12.5° to the

EW direction. Variations of the suddenly commencing type are characteristically accompanied by short-period earth-current pulsations. Among 77 cases of rapid variations of the ssc type registered in Ashkhabad, accompanying pulsations with a predominant period of from 6 to 15 sec in the recording of earth currents were noted in 59 of the cases. The distribution of the accompanying pulsations by periods is presented below.

Period, seconds	0-5	6-10	11-15	16-20	21-25	26-30	31-35
Number of cases	2	22	29	9	2	1	1

The duration of the accompanying pulsations was most frequently 2-5 minutes.

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VI. CONTINUOUS PULSATIONS AND TRAIN-TYPE PULSATIONS IN THE ARCTIC AND THE ANTARCTIC

by V. A. Troitskaya

Prior to the beginning of the IGY, observations of short-period pulsations (SPP) with periods of 10-100 seconds were being carried out predominantly in the middle and low latitudes. The classification of these pulsations into continuous ones (pc) and pulsation trains (pt), introduced by Committee Number 10 of the International Association on Geomagnetism and Aeronomy (IAGA), was worked out chiefly on the basis of data obtained at the middle-latitude stations. Therefore one of the first problems in the study of recordings of earth currents in the polar regions was to ascertain the suitability of the adopted classification for pulsations observable in the polar regions.

It was also of great interest to ascertain the peculiarities of the occurrence, in the polar regions, of SPP typical for the middle latitudes, and also to isolate cases of the simultaneous origin of SPP in the Arctic and Antarctic and to establish the regularities of their excitation. To develop a theory for pt and pc it was necessary to ascertain the peculiarities of their generation in the southern and northern polar regions, to determine their spectral distribution, the peculiarities of their diurnal course under conditions of polar night and polar day, and the seasonal course.

The results obtained up to the present permit the following preliminary conclusions to be made.

1. Continuous regular pulsations (pc) with periods of 15-40 seconds are characteristic for the polar regions as well as for the middle latitudes.

2. Pulsation trains which have such a characteristic form in the middle latitudes, in the polar regions during the years of maximum solar activity either constitute one of the elements of the polar disturbance or are manifested as a feeble individual disturbance. In both cases they are devoid of the characteristic shape of the middle-latitude trains.

3. Classification of the continuous pulsations in the polar regions lacks breadth. At the present time, it would be expedient to examine three types of continuous pulsation for the polar regions:

a) Short-period pulsations with periods of 5-15 seconds (sip--short-period irregular pulsations). In distinction from regular pc with periods of 15-45 seconds, these pulsations rapidly attenuate with latitude. Their diurnal and seasonal variation is sharply distinguished from the diurnal variation of regular pc. For sip a high degree of correlation with the polar aurorae was traced;

b) Irregular pc with periods of 50-90 seconds (pc^{o}). These pulsations are well traceable in the middle latitudes, but are especially typical and intensive in the polar regions. Their diurnal distribution is analogous to the diurnal distribution of regular pc, but somewhat more diffused. One can suppose that they form, as it were, the basic background in the polar region against which the other pulsations develop. The seasonal variation of these pulsations is sharply distinguished from the seasonal variation of regular pc;

c) Regular pc with periods of 14-40 seconds are typical for the middle latitudes, the Arctic, and the Antarctic. The diurnal variation of pc in the polar regions is similar to their diurnal variation in the middle latitudes.

4. One of the most interesting results of the investigation was isolation of the polar-night effect for regular continuous pulsations in the Antarctic and Arctic. This was manifested with particular sharpness in the Antarctic: in the middle of the polar winter the number of hours with regular pc falls abruptly.

5. The dependence of the geographical distribution of regular continuous pulsations on season is a consequence of the polar-night effect. Apparently the periods of the equinox should be the most favorable for the universal world distribution of pc.

6. During the study of the geographical distribution both of pc and pt, a large number of cases were isolated of the simultaneous disturbance of both types of pulsations in the northern and southern hemispheres. Here the pulsations were frequently observed over an enormous interval not only of latitude but also of longitude (more than one third of the earth's perimeter). The term "clear days" was introduced to denote such days.

7. It has not as yet been possible to establish any well-defined regularities with respect to the interdependence of the pt regularly observed in the middle latitudes and typical polar disturbances.

Middle-latitude trains sometimes coincide with polar disturbances or everywhere take place as trains (being sometimes expressed with the least clarity of all precisely in the polar regions), and in some cases they are observed only in the middle latitudes with comparatively calm or atypical recording in the polar regions.

8. The diurnal variation of pulsation trains in the Arctic and

Antarctic regions is similar to, and shares characteristics with that obtained for the middle latitudes.

9. The amplitudes of trains and continuous pulsations in the Arctic and Antarctic are very large and amount to tens and hundreds of millivolts per kilometer.

10. A general analysis oi the recording of pt and pc in the Arctic and Antarctic regions leads to the preliminary conclusion that pulsation trains and the polar disturbances corresponding to them are more typical of Arctic regions than they are of Antarctic regions.[1]

Initial Materials

Observations of the earth currents in the Arctic during the IGY were organized at five stations: Hayes Island, Piramida, Cape Chelyuskin, Tiksi and Lovozero. The most complete series of observations during the first year of the IGY were obtained at the Lovozero and Chelyuskin stations.[2] Therefore the results set forth below are based mainly on the data of these two stations. In the general conclusions, account is taken of the processing of the recordingsof all stations.

During the IGY, observations of the earth currents in the Antarctic were conducted at two stations: Mirnyy and Oazis. The recordings were processed for both stations for July-September 1957, and for Oazis for January-July 1958. The material from the Mirnyy station for 1958 was analyzed in part. In studying the regularities in the excitation of SPP in the polar and middle latitudes, use was made of recordings from the middle latitude stations, chiefly Alushta and Petropavlovsk-Kamchatskiy.

The results presented below were obtained mainly from the processing of earth-current recordings with a rotation of 90 mm/hour; partial use was made of recordings with a more rapid rotation (30 mm/minute).

The description and technical characteristics oi these installations are presented in the works (Ref. 1) and (Ref. 2).

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1 In mind are the Mirnyy and Oazis Stations, located within the zone of the polar aurorae.

2 The remaining three stations were late in starting regular operations.

Basic Results

1. Continuous Pulsations (pc)

The Characteristic Morphological Peculiarities of Continuous Pulsations in the Polar Regions. Pulsations in the polar regions can be divided into three characteristic classes.

1. Irregular pulsations with periods of less than 15 seconds (usually 5-15 seconds), designated by the sip index: A^v, B^v, C^v. These pulsations are expressed best of all at the Lovozero station. They attenuate rapidly with latitude.

2. Regular continuous pulsations with periods of 15-40 seconds, typical also for the middle latitudes.

3. Irregular continuous pulsations with periods of 50-90 seconds, especially intensive in the polar regions but also typical of the middle latitudes. They are designated by the index o : A^o, B^o, C^o. It is interesting to note that frequently the excitation of sip and pc^o occurs simultaneously: sip turn out to be superimposed on pc^o. Comparing the recordings of the middle-latitude and polar stations in such cases, one may become convinced that usually the irregular pulsations pc^o penetrate into the middle latitudes and that the shorter period sip pulsations attenuate rapidly, not as a rule being propagated in the middle latitudes (with certain exceptions).[1] In Figures 1 and 9, a, b, examples are presented illustrating the characteristic traits of these three types of continuous pulsation.

Distribution of Continuous Pulsations According to Period and Amplitude. In accordance with the indicated supplementary classification of continuous pulsations, Figure 2 presents the distribution of pulsations according to period for two Arctic and one Antarctic stations. The distribution shows a clear spectral distinction among the sip, pc^o, and pc pulsations. For regular pc, just as in the middle latitudes, periods of 15-40 seconds are characteristic; for irregular pc^o, periods of 50-90 seconds and for sip, periods of less than 15 seconds are typical.

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[1] According to data of recordings with a 90 mm/hour rotation and with corresponding sensitivity.

Examination of the regularities of changes of regular pc periods from month to month in the Antarctic disclosed a tendency toward a decrease in the period of pc in the transition from polar night to polar day. The amplitude of all types of continuous pulsation in both polar regions is in the order of tens of hundreds of millivolts per kilometer. In Figure 3 are presented, as an example, the distributions by amplitude for continuous pulsations of various types at the Lovozero and Oazis stations. For the Antarctic a tendency was noted for an increase in the amplitude of pulsations during the transition from polar night to polar day.

Diurnal Variation of Continuous Pulsations. The diurnal variations of regular and irregular continuous pulsations at all the polar stations display analogous traits and attest to the fact that pc and pc^{o} are excited principally in the interval of 0600-1700 hours local time with the maximum around local midday. It should be noted that the distribution of irregular continuous pulsations pc^{o} is more diffused than is the distribution of regular pc (Figure 4, a and b). As far as the distribution of short-periodically continuous pulsations sip is concerned it differs sharply (Figure 4, c).

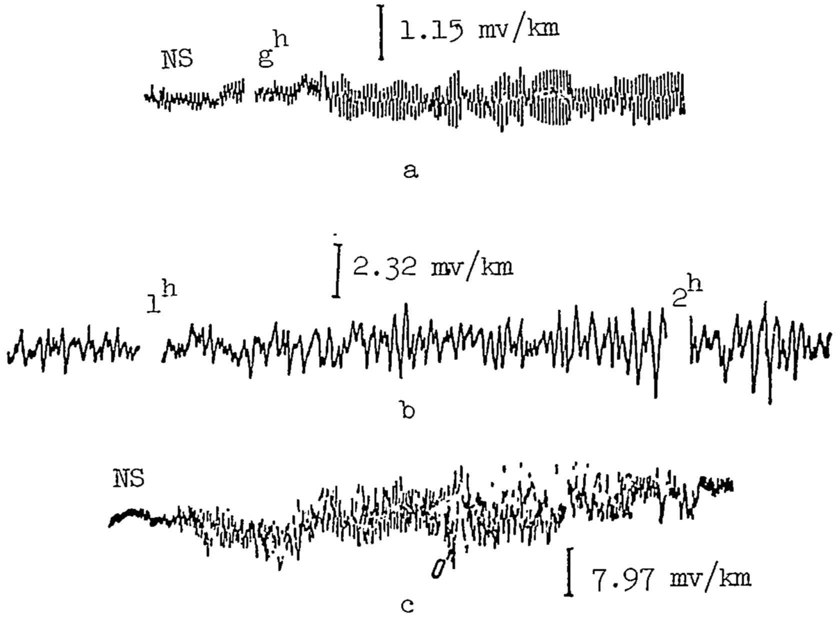


Figure 1. Examples of three types of continuous pulsation, pc.

a - regular pc (Alushta, 2 October 1957); b - irregular pc^{o} (Alma-Ata, 16 April 1955); c - polar short-period sip (Lovozero, 4-5 October 1957).

The diurnal variation of these pulsations was studied chiefly on the basis of the recordings of the Lovozero station, where they are best expressed. These pulsations originate mainly at the local midnight. A large part of the pulsations for the investigated period was registered during the interval of 1900-0800 hours, local time, with a maximum at 2200-0400 hours.

The distributions of the first two types of pc in the polar regions coincide in their character with analogous distributions in the middle latitudes. For "polar" sip, a sharply differing diurnal variation is observed. Interestingly, this diurnal variation coincides in its configurations with the diurnal variation of polar aurorae (Figure 5)[1].

Comparison of individual cases of visual and photometric observations of polar aurorae with the periods of sip excitations likewise confirms the correlation between sip and polar aurorae.[2]

Very interesting properties of regular continuous pulsations are manifested when their diurnal variation is examined month after month from polar night to polar day. These properties have so far been best investigated for the Antarctic.

Thus, for example, if one takes as 100 per cent the total number of hours with regular continuous pulsations observed for July-September 1957 in the Antarctic, 3 per cent of the number of hours with pulsations occur in July (the Antarctic winter), 12.2 per cent in August, 14.7 per cent in September, 11.5 per cent in October, 29.3 per cent in November, and 29.3 per cent in December. If only the hours with intensive continuous pulsations are considered, then in July only 0.9 per cent occurs, and in November - 25.7 per cent of the total number of cases (the data are presented for Mirnyy).

The effect of the polar night on regular continuous pulsations in the Antarctic for 1957 and 1958 is shown in Figure 6.

1 The curve of the diurnal variation of polar aurorae at the Lovozero station was constructed according to the results of visual observations of polar aurorae by V. Kononkov.

2 Reports have recently appeared in the press on research concerning pulsations with periods approximating sip. It is reported that precisely for these pulsations is the best correlation found with magnetic activity (Kp) and with polar aurorae in the USA and Canada (Refs. 3 and 4).

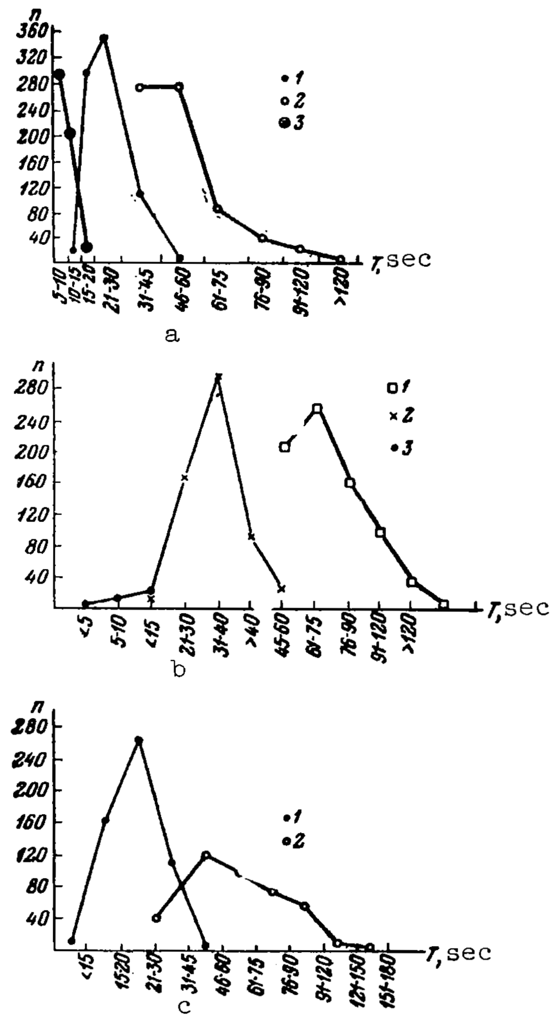


Figure 2. Distribution of pc by periods (August 1957-June 1958).

a - Lovozero; 1-A + B + C; 2-A^{O} + B^{O} + C^{O}; 3-A^{V} + B^{V} + C^{V};

b - Chelyuskin; 1-A^{O} + B^{O}; 2-A + B; 3-A^{V} + B^{V};

c - Oazis; 1-A + B + C; 2-A^{O} + B^{O} + C^{O}.

The graphs presented confirm the special value of the organization of observations over the complex of electromagnetic phenomena in the polar regions. Actually, the observations of continuous pulsations in the Antarctic in the course of a half year have yielded physically clear regularities which could not be isolated in the middle latitudes in the course of many years of observation.

Seasonal Variation of Continuous Pulsations. Analysis of the diurnal variation of regular pc in the Antarctic has yielded convincing proof of the connection of these pulsations with illumination (the polar-night effect). Study of the seasonal variation of regular pc in the Arctic has confirmed this connection.

In Figure 7 is presented the seasonal variation of regular continuous pulsations in the Arctic (Lovozero) and the Antarctic (Oazis) regions.

In spite of the fact that data are available only for 1 year, the curves show a direct relationship of pc excitation to illumination and have a correspondingly opposite distribution for the Arctic and Antarctic regions. A direct connection with illumination has been established only for regular pc. The seasonal variation of irregular pc^{o} and the very short-period sip differs sharply from the seasonal variation of regular pc. This fact, in addition to the different spectral distribution and the different diurnal variation (especially for sip), once again confirms the necessity for dividing continuous pulsations at least into two classes in the middle latitudes and into three classes in the higher latitudes.

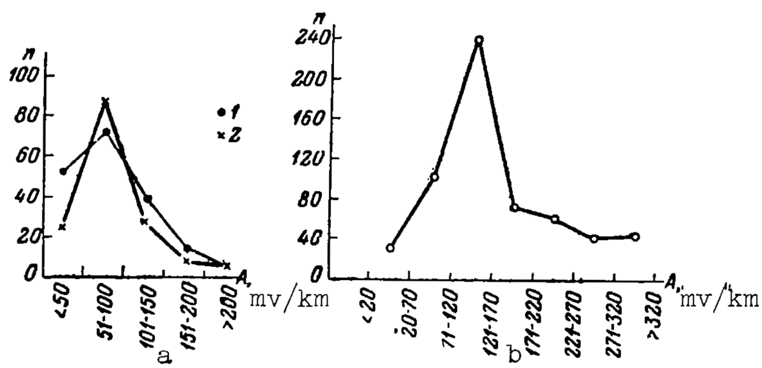


Figure 3. Distribution of continuous pulsations by amplitude.

a - Lovozero (January-June 1958); 1-A^{o} + B^{o}; 2-A^{v} + B^{v};
b - Oazis.

The seasonal variation of irregular continuous pulsations in the Arctic and Antarctic regions is presented in Figure 8a. From it can be seen that the largest number of pulsations occurs during the equinoxial months. The seasonal variation of shortest-period pulsations (sip) is analogous to the seasonal variation of pc^{o} (Figure 8d). However, the

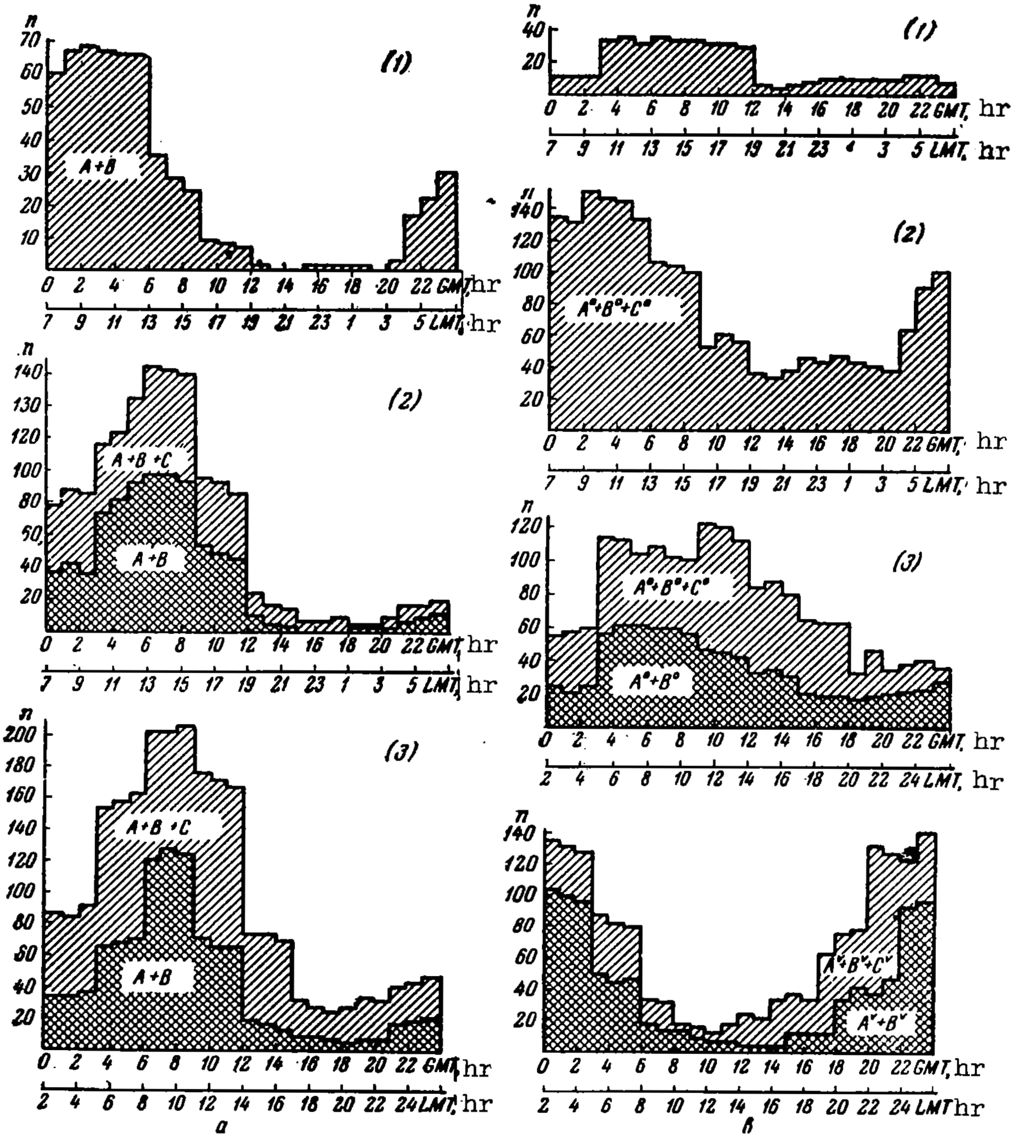


Figure 4. Diurnal variation of continuous pulsations in the Arctic and Antarctic regions.

a - pc at the Chelyuskin (1), Oazis (2) and Lovozero (3) stations;

b - pc^{o} at the Chelyuskin (1), Oazis (2) and Lovozero (3) stations;

c - sip at the Lovozero station. In the histograms, data are used for the Oazis station for August 1957-June 1958; for the Lovozero station for June 1957-June 1958.

frequency of their appearance is less than the frequency of the appearance of irregular pulsations.

Once again it should be remembered that the shortest period continuous pulsations sip, usually are superimposed on irregular pulsations pc^{o}, although not a few cases without the superimposition of sip are observed.

Geographical Distribution of Continuous Pulsations. In spite of the clear relationship of the excitation of regular pc to local time, cases are well-known of the excitation of these pulsations simultaneously over a vast territory.

The regularities of excitation of pc over an area encompassing both hemispheres and a great longitudinal interval can probably be subordinated to the control of universal time, which under ususal conditions is masked by the control of local time.

For isolating the regularities of worldwide excitation of pc, special correlation tables were drawn up (see Appendix). Days when pc were observed simultaneously in the Arctic region, in the middle latitudes, and in the Antarctic region, and also over great longitudinal interval, received the name of "transparent" days.

Days can vary in transparency. Days are encountered when pulsations arise simultaneously in both polar regions of the earth and in a longitudinal interval greater than one third of the perimeter of the earth's sphere. Sometimes days are transparent for both polar caps and the middle latitudes but in a comparatively narrow longitudinal interval.

In examining the regularities of the simultaneous excitation of continuous pulsations in the Antarctic and Arctic regions the above-described polar-night effect on the pc should be kept in mind. Indeed, if the recordings of the Antarctic stations are compared with the recordings of a middle-latitude station, for example in July, it turns out that pulsations clearly expressed in the middle latitudes are traceable principally as traces of pulsations in the Antarctic (with the exception of some well-matching cases). If then the recordings of these stations are compared for November-December (the Antarctic summer), an opposing pattern takes place - the middle latitudes repeat, with diminished intensity, the intensive pulsations observable in the Antarctic. The facts described above are illustrated by two generalized excerpts from the correlation tables for July and November 1957 (see Appendix). The excerpts were made for the interval of 0000-0300 hours, universal time, for the middle-latitude and Antarctic stations.

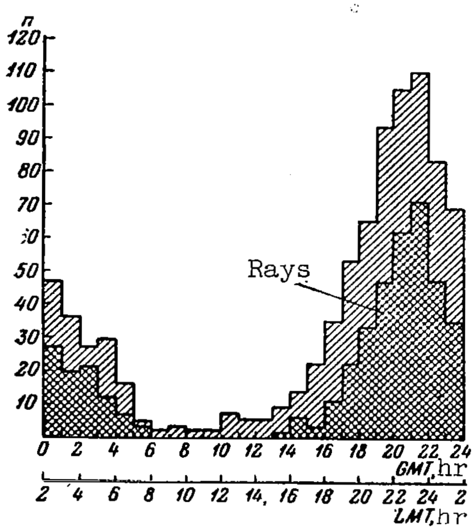
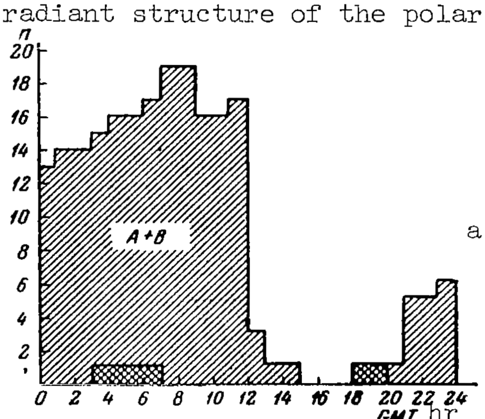


Figure 5. Diurnal variation of polar aurorae at the Lovozero station in 1957-1959. The figure located inside the histograms indicates the radiant structure of the polar aurorae.



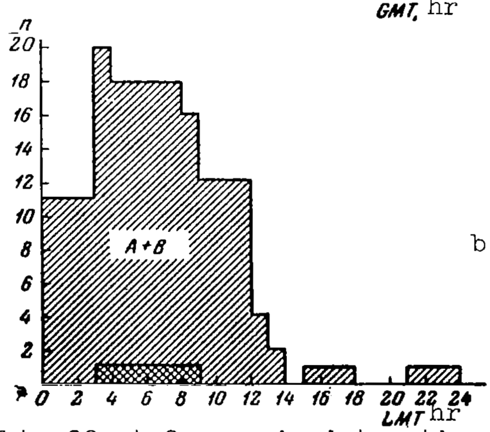


Fig. 6. The polar-night effect for pc in Antarctica in Nov. 1957(a) and Dec. 1958(b). The figures displayed inside the histograms indicate the no. of cases of intensive pc (A+B) registered in July. (Antarctic winter).

Thus the geographical latitudinal distribution of continuous pulsations depends on the season.

Investigation of the problem of the regularities of the occurrence of transparent days for pc according to longitude has only begun at the present time. There is a definite tendency towards the intensifications of transparency during magnetic storms and on the days following these storms.

Clear days occur, however, even during quiet or weakly disturbed states of the magnetic field.

In Figure 9 are presented photocopies of recordings on the clear days of 13 February 1958 (after the storm of 11 February) and 2 October 1957 (a relatively quiet day). In the second example we have used a photocopy of the recording of the earth currents sent by Doctor A. Fogt for the Parmaribo station (Western Hemisphere).

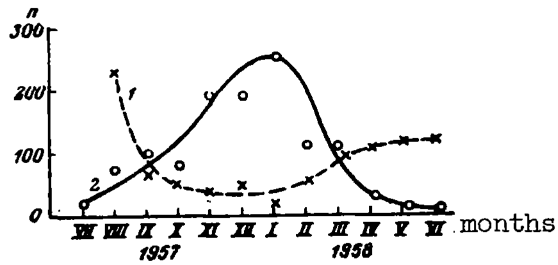


Figure 7. Seasonal variation of regular continuous pulsations in the Arctic and Antarctic regions. 1 - Lovozero; 2 - Oazis.

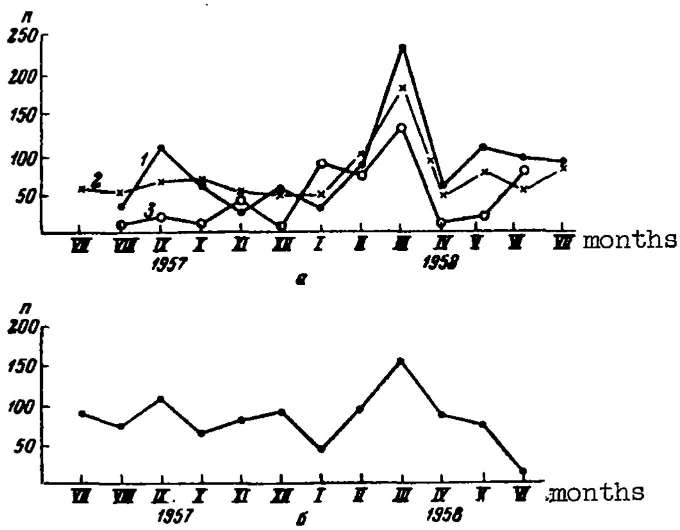


Figure 8. Seasonal distribution of pc^{o} (a) and sip (b) in Antarctica. 1 - Lovozero; 2 - Chelyuskin; 3 - Oazis.

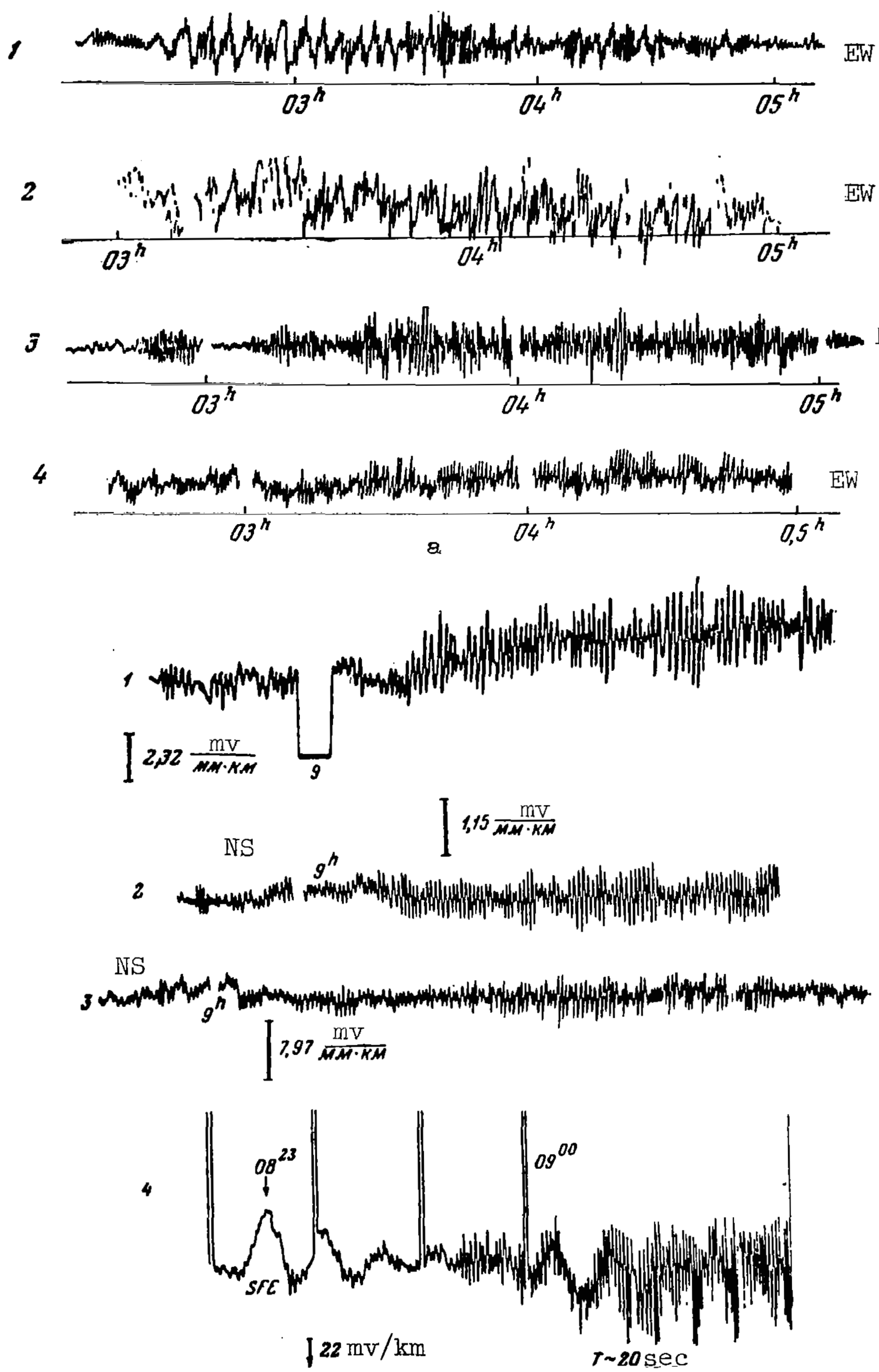


Figure 9. Examples of transparent days for pc. a - 13 February 1958; 1-Lovozero; 2-Oazis; 3-Mikhaylovka-na-Sakhaline; 4-L'vov; b - 2 October 1957; 1-Alma-Ata; 2-Alushta; 3-Lovozero; 4-Paramaribo. Universal time.

As was already stated, the shortest-period pulsations sip are the most highly localized, i.e., diminish most rapidly in amplitude. Nonetheless, in a number of cases they are registered simultaneously at the polar and the middle-latitude stations. Study of these pulsations on rapid, more sensitive registers (30 mm/minute), which has recently begun, permits us to trace systematically the regularities of their distribution both within the limits of the polar zone and in the middle latitudes.

2. Pulsation Trains (pt)

The Characteristic Morphological Peculiarities of Pulsations Trains in the Polar Regions. Pulsation trains in the polar regions do not exhibit the typical shape by which they are characterized in the middle latitudes,[1] by the processing of the recordings made at the polar stations, the detection of pulsation trains was reduced to first tracking a train in the middle latitudes, and then to identification of a disturbance taking place at that moment in the Arctic or Antarctic with the pulsation train. A polar disturbance frequently corresponding to pulsation trains in the middle latitudes usually consists of three elements: a microbay with a duration of 4-6 minutes, pulsations similar to trains with respect to period, and superimposed very short-period pulsations of the sip type described above.

An interesting morphological peculiarity of pulsation trains in the middle latitudes and in polar regions, and also of the polar disturbances described above, is their complex microstructure for the shorter-period pulsations ($T \sim 1$-15 seconds). These pulsations are always observable on rapid recordings (30 mm/minute) when a train or a polar disturbance is noticeable on recordings with a rotation of 90 mm/hour.

In Figure 10, examples are provided of polar disturbances and pulsation trains which illustrate the peculiarities of their development in the polar and middle latitudes.

Figure 10a is an example of a pulsation train well expressed in the Arctic region (Chelyuskin) and in the middle latitudes (Alushta), and noticeable in the Antarctic only as a weak trace of a disturbance.

Figure 10b is a case where two disturbances of the pulsation-train type are intensively expressed in the Antarctic region. These two

[1] It should be noted that reduction of the material for 1959-1960 has shown that with a decrease in solar activity, the number of cases of appearance in the polar region of pulsation trains with characteristic middle latitude traits increases.

Examples of polar disturbances and pulsation trains in the polar and middle latitudes.
(Figures 10a-10e, pages 52-56)

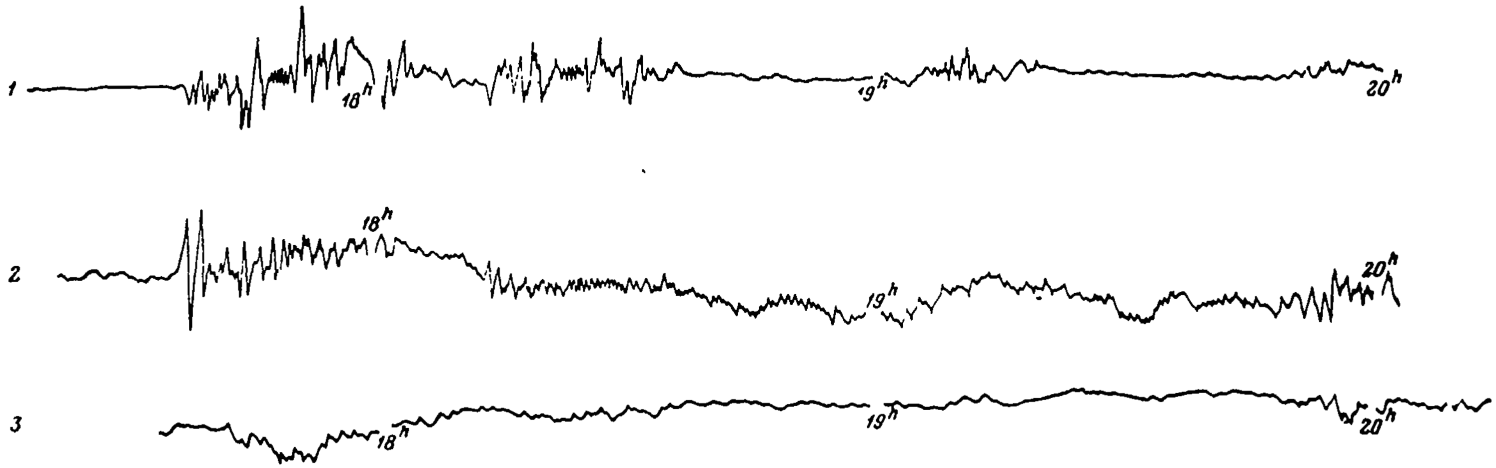


Figure 10a. 13 April 1958; 1 - Chelyuskin; 2 - Alushta; 3 - Mirnyy

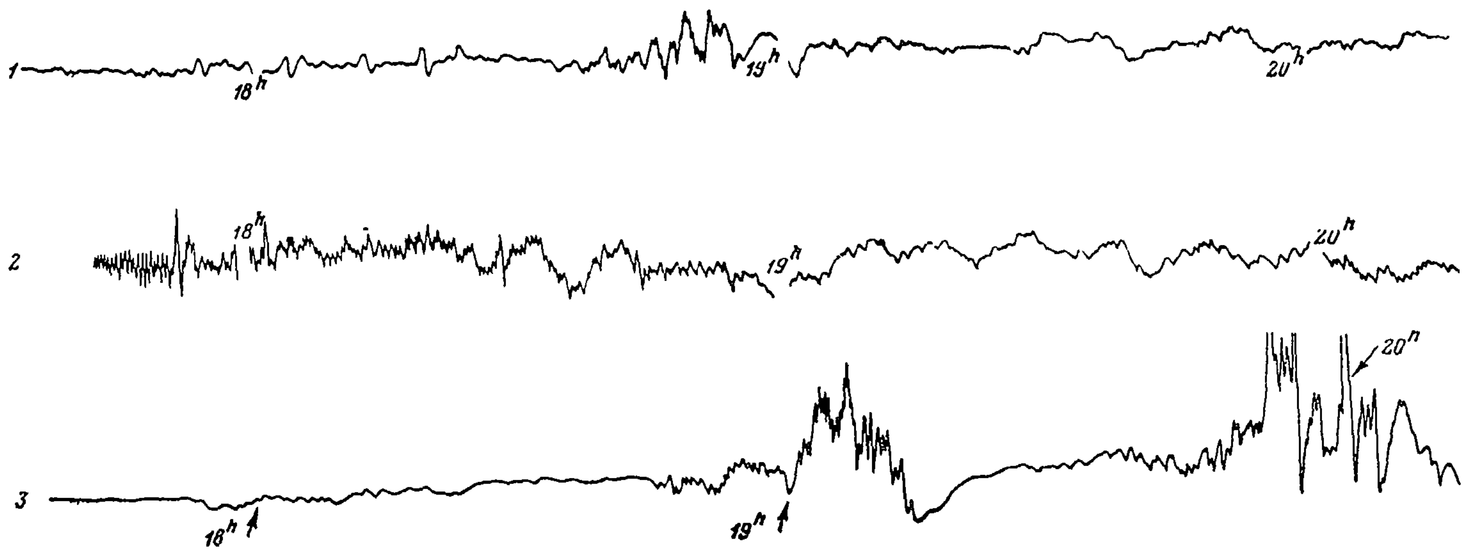


Figure 10b. 11 April 1958; 1 - Chelyuskin; 2 - Alushta; 3 - Mirnyy.

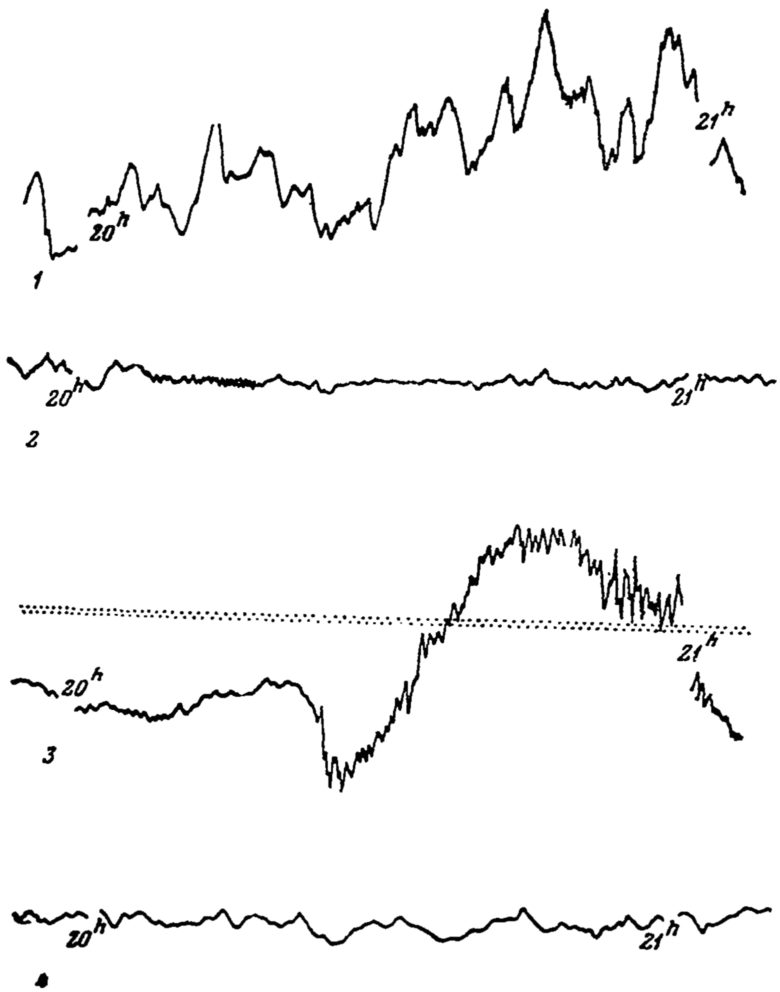


Figure 10c. 24 March 1958; 1 - Barentsburg; 2 - Chelyuskin; 3 - Alushta; 4 - Oazis.

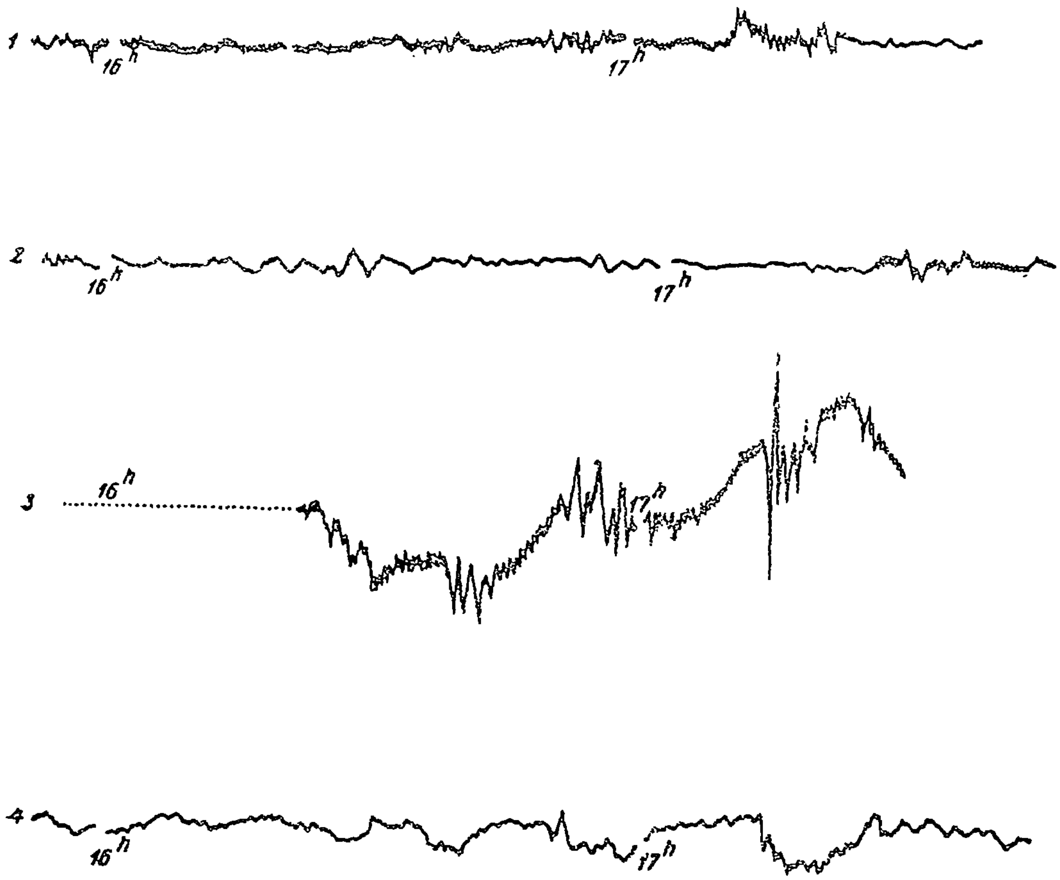


Figure 10d. 20 March 1958; 1 - Barentsburg; 2 - Chelyuskin; 3 - Alushta; 4 - Mirnyy.

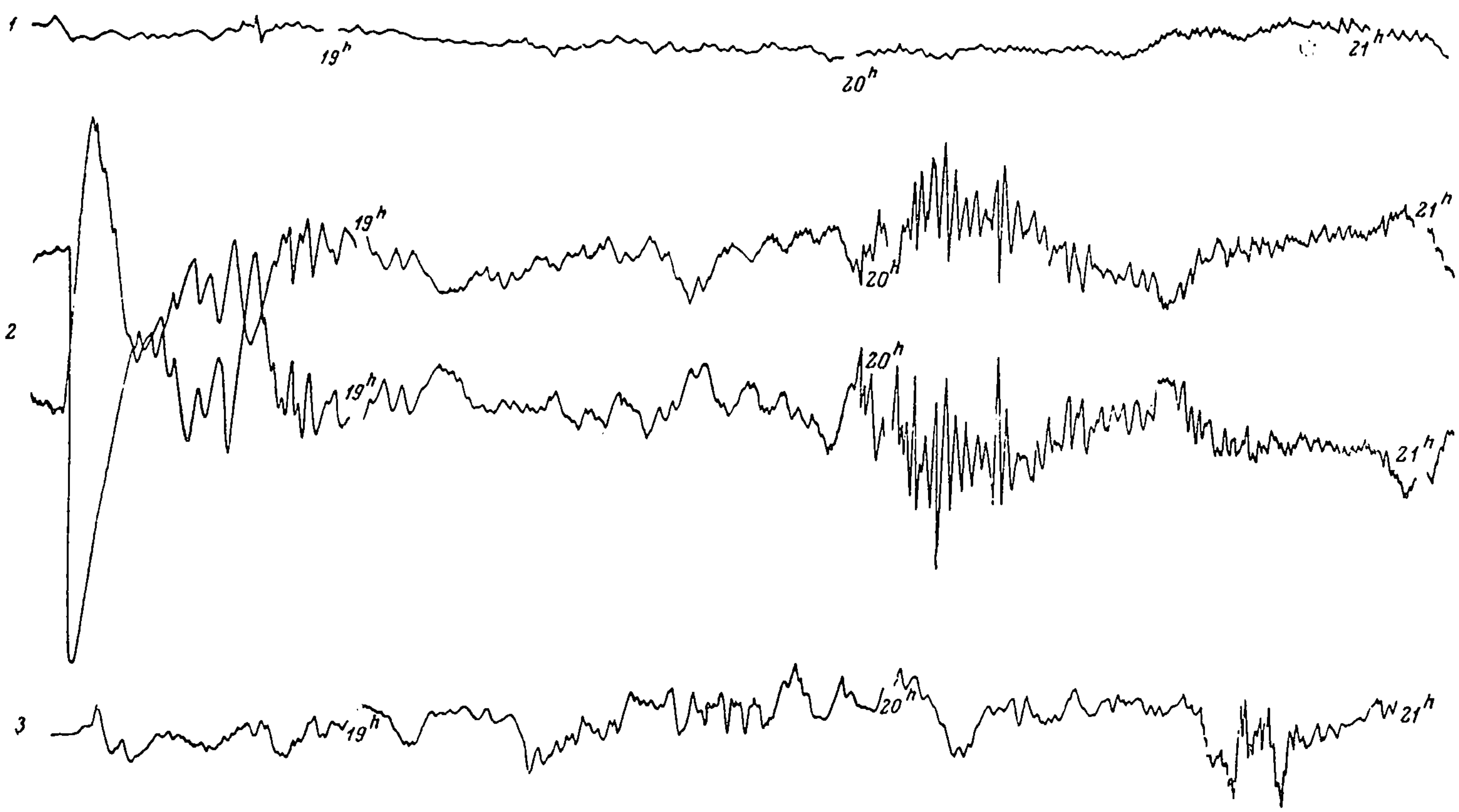


Figure 10e. 14 April 1958; 1 - Chelyuskin; 2 - Alushta; 3 - Mirnyy.

onsets were not manifested in the middle latitudes (Alushta). In the Arctic only the first one occurred, the intensive part of the onset in the Arctic region anticipating the onset of the disturbance in the Antarctic region.

Figure 10c is a case of the intensive onset, in the middle latitudes, of disturbances of the train type not accompanied by noticeable disturbances of the train type in the Arctic and Antarctic regions.

Figure 10d is a typical example of a series of pulsation trains in the middle latitudes detectable in the Arctic and Antarctic only as very weak traces.

Figure 10e is a case of pulsation trains in a bay in the middle latitudes to which corresponds no onset of any clarity whatsoever in the Arctic or the Antarctic region.

The photocopies show that the character of the disturbance of pulsation trains in the middle and polar latitudes is complex and dissimilar from case to case. Up to the present time, the regularities of the connection between the polar disturbances described above and the pulsation trains in the middle latitudes have as yet not been explained. The available data permits us to assume that part of the pulsation trains observable in the middle latitudes is actually a trace of the polar disturbance (as has been indicated earlier), whereas in a number of other cases such regularity is not clearly detectable.

Periods and Amplitudes of Pulsation Trains. Figures 11 and 12 show the distribution of pulsation trains according to period and amplitude for the Arctic and Antarctic stations (in the case of a polar disturbance, the period was determined for the middle-latitude train-type pulsations which, according to the accepted terminology, comprise the second element of a polar disturbance). The graphs show that periods of trains in the polar regions lie principally within the limits of 5-90 seconds. The amplitudes of train-type pulsations in the polar regions amount to tens and hundreds of millivolts per kilometer.

Diurnal Variation of Pulsation Trains. The diurnal variation of pulsation trains and the polar disturbances corresponding to them in the Arctic and Antarctic possesses all the traits pertaining to analogous distributions in the middle latitudes. In Figure 13 is presented the diurnal distribution of pulsation trains for the Oazis and Lovozero stations. These distributions have the same character at other polar stations as well.

The graphs show that the influence of local time undoubtedly, plays a chief role in the possibility of the appearance of pulsation trains at Arctic and Antarctic stations. However, in distinction from

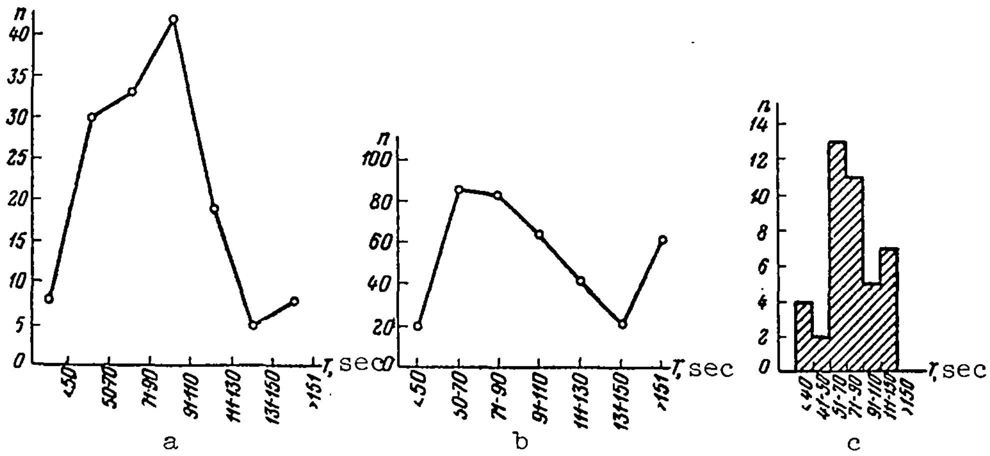


Figure 11. Distribution of pulsation trains by periods in the Arctic and Antarctic regions.
a - Oazis (August 1957-June 1958); b - Lovozero (August 1957-June 1958); c - Chelyuskin (August-December 1957).

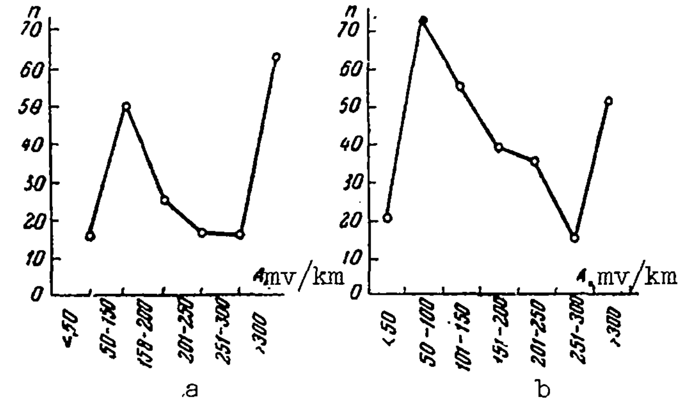


Figure 12. Distribution of pulsation trains by amplitude in the Arctic and Antarctic regions in August 1957-June 1958.
a - Chelyuskin; b - Lovozero.

continuous pulsations, where this connection with the local time passes into a direct dependence on illumination, this effect is more complex for pulsation trains. Changes in the number of pulsations trains from month to month do not display an effect analogous to the polar-night effect for continuous pulsations. This probably indicates a more direct connection between pulsation trains and the corpuscular radiation of the sun. Possibly this type of pulsations is also divisable into subtypes, the regularities of whose excitation are various.

Seasonal Variation of Pulsation Trains. The seasonal variations of pulsation trains, and of the polar disturbances united with them in one class, has in the Arctic and Antarctic regions a clear maximum in February-March 1958 (Figure 14). For the middle latitudes, data on the seasonal distribution are contradictory. In Japan, the reduction of earth-current observations covering many years has also yielded results which indicate the predominance of pulsation trains in the equinoxes (Ref. 5).

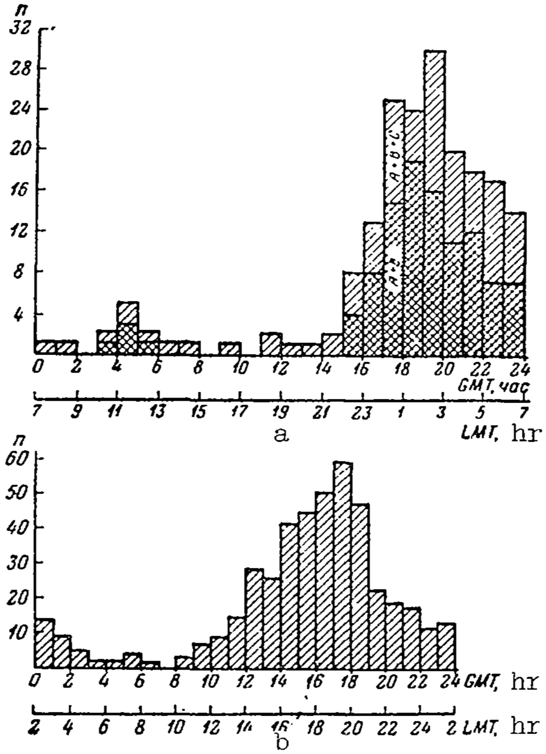


Figure 13. Diurnal variation of pulsation trains in the Arctic and Antarctic regions in August 1957- June 1958. a - Oazis; b - Lovozero.

Geographical Variation of Pulsation Trains. Up to now, the regularities of the excitation of pulsation trains simultaneously in the Antarctic and Arctic have not been studied. Recordings of earth currents in the Arctic and Antarctic, correlated by parameters, have permitted correlation tables to be compiled on the basis of which cases of the simultaneous excitation of pulsation trains in the Arctic and Antarctic regions and in the middle latitudes were studied. For pulsation trains as well as for continuous pulsations, the concept of a transparent day was introduced. Investigation of the conditions of clearness for trains has just begun. However, one can already say that the number of cases of the simultaneous excitation of pulsation trains or polar disturbances in the Arctic and Antarctic is relatively large.

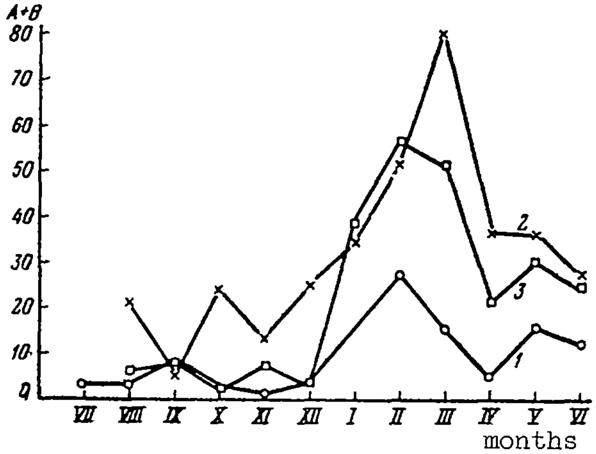


Figure 14. Seasonal variation of pulsation trains in the Arctic and Antarctic regions in July 1957-June 1958. 1 - Oazis; 2 - Lovozero; 3 - Chelyuskin.

It should be noted that conditions of transparency vary. Sometimes pulsation trains are registered simultaneously in both polar regions of the earth's sphere and in a comparatively small longitudinal interval. Sometimes, along with simultaneous excitation in the Arctic and Antarctic regions, trains are detectable in a longitudinal interval greater than one third of the earth's perimeter (see Appendix, Table 1). Preliminary quantitative analysis of cases of the simultaneous excitation of pulsation trains in the Arctic and Antarctic regions and the middle latitudes permitted the following noteworthy fact to be observed: pulsation trains appear to be disturbances more typical of the Arctic region than of the Antarctic. The seasons of greatest transparency for them are, apparently, the equinoxes.

APPENDIX

Table 1

Train On 3 August 1958

Station	Latitude	Longitude	Initiation of train	End of train
Hayes Island	70°54'N.	156°29'	1351 hrs. P.D.*	1425 hrs.
Chelyuskin	65 58	176 24	1330 " P.D.	1430 "
Tiksi	60 08	191 08	1330 "	1450 "
Petropavlovsk	44 24	218 14	1300 "	1500 "
Irkutsk	41 19	175 28	1250 "	1500 "
Yuzhno-Sakhalinsk	40 24	204 15	1300 "	1500 "
Alushta	40 56	113 36	1335 "	1420 " (Trace of Train)
Alma-Ata	33 10	151 03	1332 hrs.	1420 hrs.
Oazis	77 43 S.	159 53	1347 " P.D.	1440 "

Train on 14 August 1958

Station	Latitude	Longitude	Initiation of train	End of train
Hayes Island	70°54'N.	156°29'	1730 hrs. P.D.*	1848 hrs.
Piramida	74 27	132 56	No	Tape
Chelyuskin	65 58	176 24	1732 hrs. P.D.	1850 hrs.
Tiksi	60 08	191 08	1733 "	1741 "
Lovozero	62 45	127 18	1730 "	1829 "
Borok	52 53	123 20	1732 "	1837 "
Petropavlovsk	44 24	218 14	1732 "	1738 "
Irkutsk	41 19	175 28	No	Tape
Yuzhno-Sakhalinsk[1]	40 24	204 15	1732 hrs.	1756 hrs.
L'vov	47 00	104 09	1732 "	1837 "
Alushta	40 56	113 36	No	Tape
Alma-Ata	33 10	151 03	1730 hrs.	1740 hrs.
Oazis	77 43 S.	159 53	1735 "	1952 "

* P.D. - Polar disturbance.

[1] In the Russian original two values are assigned to the hyphenated term. The more plausible arrangement is typed above. The original is below.

Южно-Саха-линск	40 24	204 15	17 32 17 32	17 56 18 37
Львов	47 00	104 09	Нет лент	
Алушта	40 56	113 36		
Алма-Ата	33 10	151 03	17 30	17 40
Оазис	77 43 ю.	159 53	17 35	19 52

Sample of Correlation Table* Table 2.

Interval of 0000-0300 Hours
Greenwich Time

July 1957

Day of the Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Antarctica	—	—	—	—	C	—	C	C	C	—	—	—	—	—	—	—
Middle Latitudes	—	—	—	—	A—B	—	A	A	BA	—	B	—	B	B	B	—

Day of the Month	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Antarctica	—	C?	C?	—	C?	C??	NL	C?	NL	—	Interference				
Middle Latitudes	AA—	B	A—B	—	A	A	A	B	B	—	Interference				

November 1957

Day of the Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Antarctica	C—B	A	C	B—A	B	C	B	C—B	C	C—B	C—B	C—B	C—B	B	C—B	C
Middle Latitudes	C—B	B	B	B	B	—	—	—	—	—	B	—	—	A	—	—

Day of the Month	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Antarctica	C	—	—	B	B—A	C—B	B—A	B	B	C	C	—	C	—	—
Middle Latitudes	—	—	—	B	B—A	B	B—A	—	—	—	—	—	—	—	—

* NL - no tape; C - weak continuous pulsations; AB - characteristic intensive pulsations; C? - C?? - doubtful and very doubtful cases of continuous pulsation.

In conclusion the author expresses deep gratitude to N. Nikitina, E. Zubareva, G. Korobkova and I. Fel'd (Arctic and Antarctic Scientific Institute of the Main Administration of the Northern Sea Route) who organized and conducted the observations at the Arctic stations and to L. Baranskiy, N. Naumenkov, V. Bobynin, I. Rokityanskiy, O. Okhatsimskaya, Yu. Rastrusin, R. Shchepetnov, K. Zybin and V. Kononkov (Institute of Physics of the Earth, Academy of Sciences USSR), who conducted the observations in the Antarctic, at the middle-latitude stations, and at the Lovozero station. The author considers it his duty to note also the great amount of work done by the scientific workers of the Institute of Physics of the Earth N. Sukhareva and M. Mel'nikova, and by the technical workers of the Institute in processing the data of the observations.

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VII. PRELIMINARY RESULTS OF THE EARTH CURRENT OBSERVATIONS AT TIKSI BAY

by

E. P. Zubareva

A Short Description of the Installation

The continuous registration of short-period pulsations of the earth's electromagnetic field according to the program of the IGY began at Tiksi Bay on 15 February 1958.

In the first period of the observations (February - September 1958), the recording was carried out at rotation speeds of 0.5 mm/sec and 90 mm/hr from overhead lines 500 meters long placed crosswise near the village of Tiksi (Ref. 1). The operation of the electric power station and of various electrically driven installations created very strong noise on the NS-component in the form of sharp overshoots at the 90 mm/hr rate and a diffuse recording line at the 0.5 mm/sec rate.

In the middle of September 1958 the earth-current station was transferred to a geophysical settlement located about 6 kilometers from the shore of the bay. The receiving lines were laid on the surface of the ground in swampy tundra transversed by a chain of small ridges which consisted of original outcrops and places composed of clay shale and decomposed quartz. The electrodes (lead plates measuring 750 x 500 x 3 mm) were grounded at a depth of 2 meters and were placed on the geographical meridian and parallel. The dispersion of the electrodes was cross-shaped. The interelectrode resistances vary according to the extent of soil freezing from 1×10^3 to 3.5×10^6 ohms for the EW line and from 1×10^3 to 5×10^6 ohms for the NS line.

Up to 26 April 1959, the recording was carried out with lines 1 km long at rates of 0.5 mm/sec, 90 and 22 mm/hr. The sensitivity of the installations for 90 and 22 mm/hr varied from 0.5 to 2.5 mv/km x mm for the EW element and from 2 to 13 mv/km x mm for the NS element. In order to reduce the intermediate resistances, new electrodes were made similar to the previous ones but situated at a depth of 0.4, 0.5 meters between layers of coal dust over which was poured a concentrated solution of NaCl. With the approach of summer, and also due to the new placement of the electrodes, the interelectrode resistances were reduced to 2,000 ohms on the NS line and to 9,000 ohms on the EW line.

Since 15 June 1959 lines 1 km long have been used for high-speed

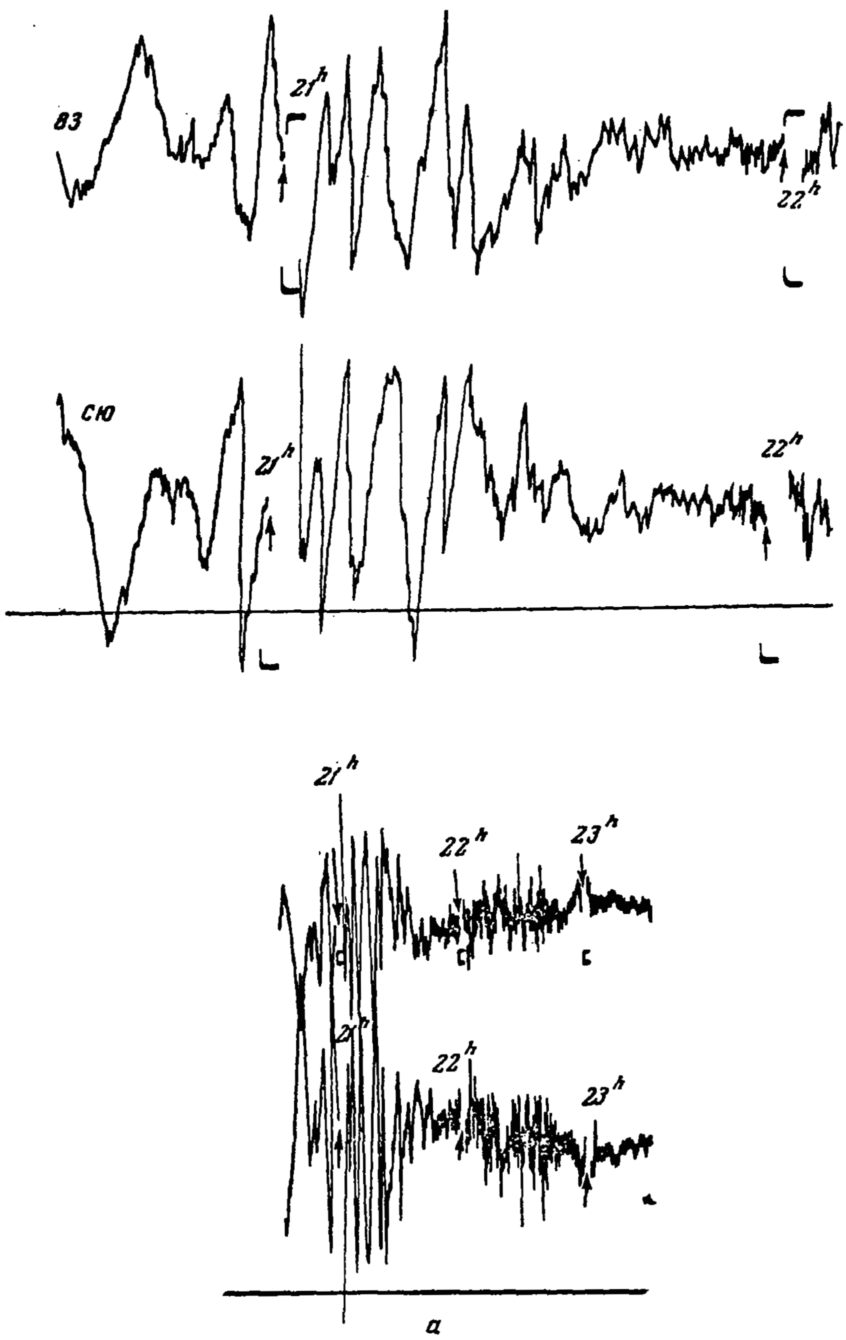

Fig. 1. Examples of pulsation types.
a - pulsation trains (rotation rates of 22 and 90 mm/hr)

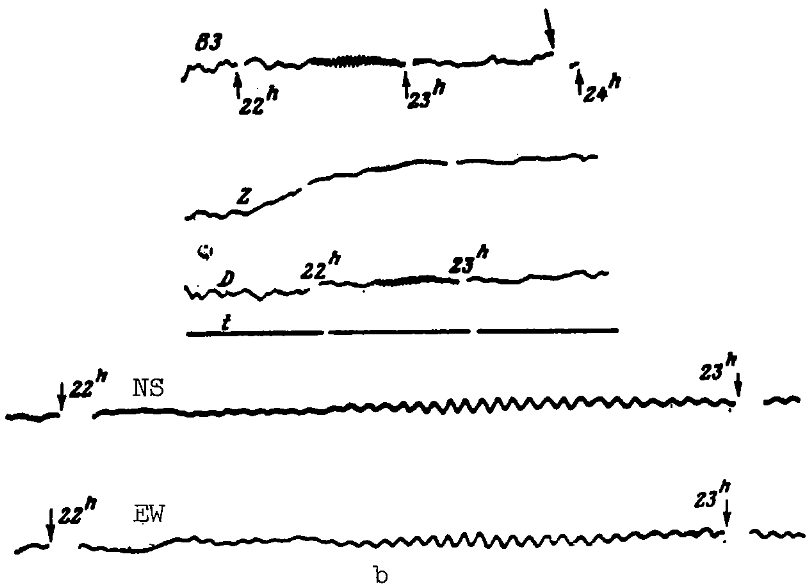

Fig. 1. b - gigantic pulsation on tellurograms (rotation rates of 22 and 90 mm/hr) and on magnetogram, 6 April 1958. Universal time.

installation(rotation at 0.5 mm/sec), and for the slowly running installations (rotation at 90 and 22 mm/hr), lines 0.5 km long were placed in an L-shaped pattern so that the southern and western electrodes of the first installation are respectively the western and northern electrodes for the second installation. The common (southeastern) electrode is under the same conditions as all the remaining ones. The interelectrode resistances for the slowly running installations have values in the order of 1480 ohms (NS) and 1460 ohms (EW). The recording sensitivity of the slowly running installations is in the order of 4 mv/km x mm for the NS elements and 1 mv/km x mm for the EW element. The direction from south to north and from west to east was adopted as the positive current direction.

Preliminary Results of the Reduction of Tellurograms

From the beginning of the observations to 1 May 1959, 939 tellurograms were obtained at the rate of 90 mm/hr and 176 at the rate of 22 mm/hr. Upon reduction, pulsations of two types were isolated: continuous pc with periods of 10-40 secs, and trains pt with periods of 40-80 secs (Refs. 2, 3). Pulsation trains well-expressed on the recordings of middle-latitude stations have a completely different shape in the

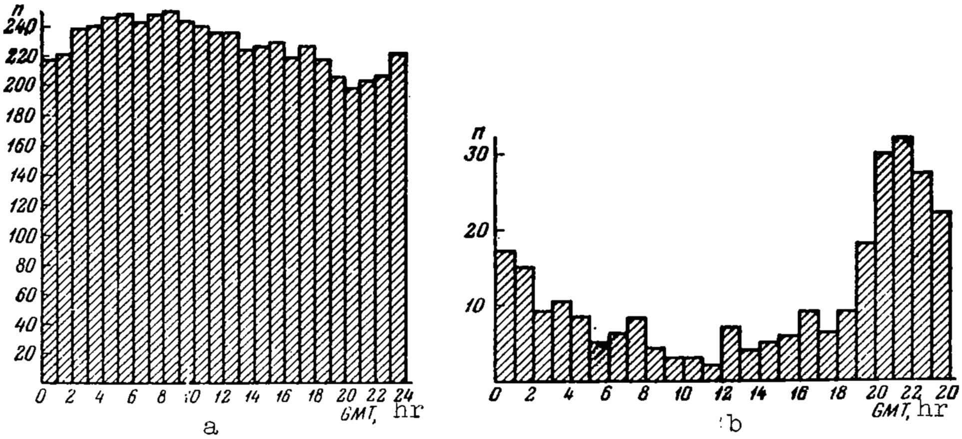

Fig. 2. Diurnal distribution of continuous pulsations (a) and trains (b) according to data for February-December 1958 (without October).

Arctic (Fig. 1) because of the high activity of the earth currents. The amplitude of the trains varies, depending on the disturbance, from 20 to 150 mv/km x mm. Continuous pulsations are similar in form to the corresponding pulsations in the middle latitudes, but are characterized by a higher amplitude (in the order of 1-50 mv/km x mm).

The diurnal variation of both types of pulsation was found. It turned out that in February-June 1958 the diurnal variation of pc and pt at the Tiksi station is analogous to the distribution obtained at central Asian stations (Ref. 4). A noticeable maximum occurs at 2000-2200 hr for pt and at 0200-0800 hr for pc (Fig. 2). In August-September 1958 the diurnal distribution of pt was very indeterminate. A similar absence of clear extremes of distribution is characteristic also for continuous pulsations, registered with the help of a loop having a diameter of 28.5 meters placed in the area of the geophysical town on the photo-attachment of an S-180 camera.

A gigantic pulsation, a very rare type of pulsation in the Arctic, was observed on 6 April 1959 in the recordings of the earth currents and magnetic field. It appeared at 2226 hr and lasted around an hour with a period of 90 sec. The maximum amplitude of the pulsations in the EW components reached 2.7 mv/km and 14.5 mv/km in the NS ones, H was 14 gamma (Fig. 1b).

In addition to determining the diurnal varition for each hour of recording, the maximum amplitude of the pulsations in millivolts per

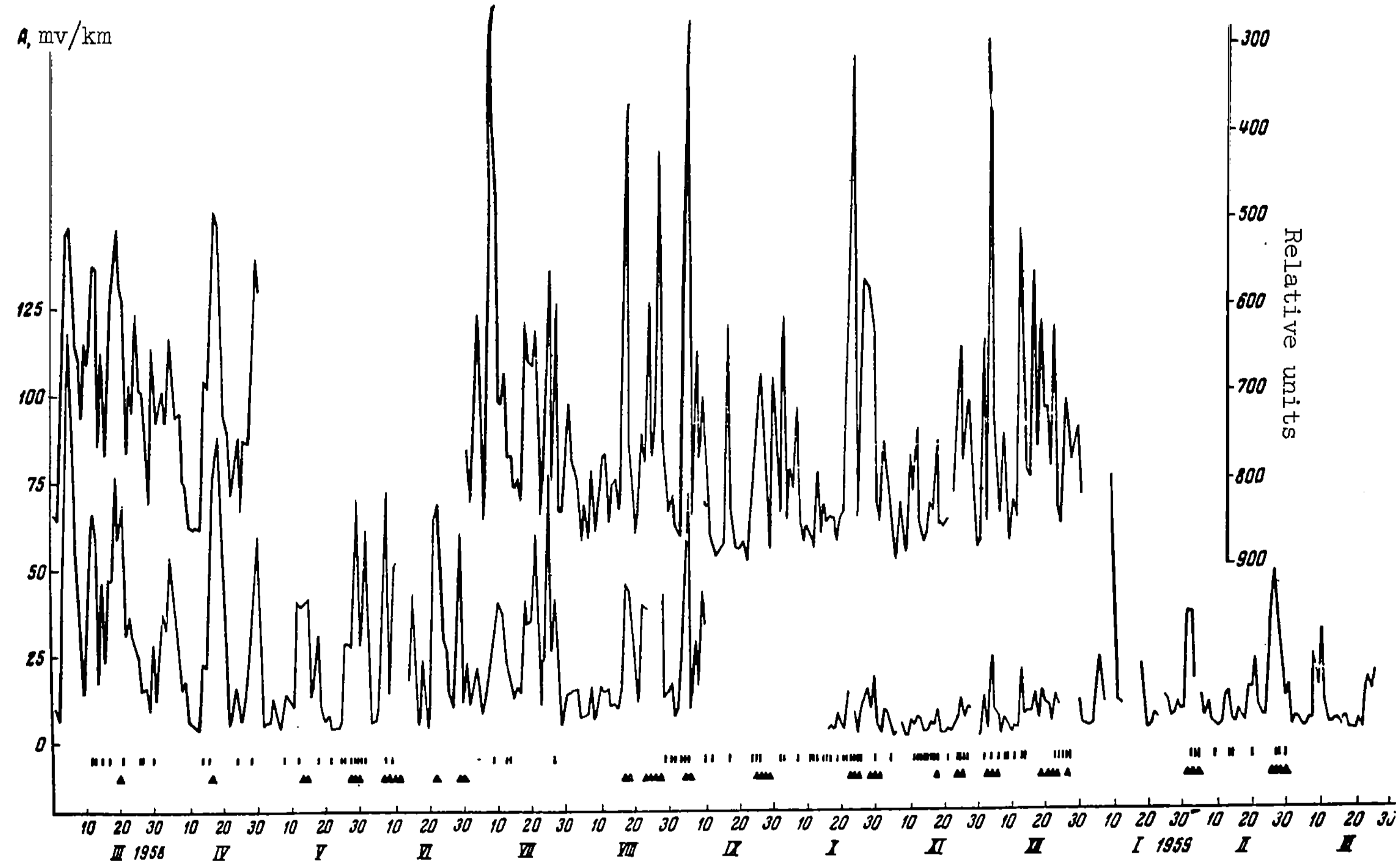

Fig. 3. Comparison of activity of the earth currents with other geophysical phenomena. Upper curve - average diurnal values of the maximum amplitudes of the horizontal component of the magnetic field in relative units; lower curve - average diurnal values of the maximum amplitudes of the latitude component of the telluric field in mv/km. The triangles mark the moments of ionospheric disturbances; the vertical strokes mark the moments of the appearance of radio echoes from polar aurorae.

kilometer was found. During the reduction of tellurograms obtained in the Bay of Tiksi (February-September 1958, rotation speed 90 mm/hr), the amplitude of the greatest pulsation in the period of each hour was taken as the maximum amplitude. Recordings of the meridional element for this period are not included in the reduction because of strong noise. Since October 1958 the maximum amplitude for both components has been determined at the rate of 22 mm/hr. As a result, the average diurnal values of the maximum amplitudes for each month were obtained. It was observed that both during magnetic storms and on quiet days the currents at a distance of 1 km from the shore of the bay are more intensive than at a distance of 6 km (the geophysical town).

In order to compare the activities of the telluric and the magnetic field, the average diurnal values of the maximum amplitudes of the latitudinal component of the earth currents and the horizontal component of the magnetic field in the Bay of Tiksi were contrasted (Fig. 3).

Owing to the broad complex of geophysical observations in the Bay of Tiksi, the results of these observations may be compared. It was noted that radio signals from polar aurorae and disturbances in the ionosphere arise simultaneously with strong magnetic disturbances and disturbances of the earth currents (Fig. 3). In the immediate comparison of the tellurograms and magnetograms, a significant similarity was noted in the recordings of the latitudinal component of the earth currents and the vertical element of the magnetic field. An analogous result was obtained from observations in the Antarctic at the Mirnyy station (Ref. 5). The meridional component of the earth currents in the Bay of Tiksi is externally similar to the horizontal component of the magnetic field, whereas an opposite effect was observed for the Cape Vykhodnoy station (Ref. 6).

During severe magnetic storms, the greatest coincidence is observable in the recordings of elements of the magnetic field and of earth current components, disturbances of the latter being more clearly expressed.

To find the average monthly diurnal variation of both of the earth-current components, tellurograms with quiet recording for 5-10 days of each month were selected and analyzed. Variations of the potential gradient for each of the days were obtained by subtracting the average diurnal value from the hourly ordinates. On the basis of these data, average monthly variations of the potential gradient for June-December 1958 and January-April 1959 were plotted for the EW components, and for October-December 1958 and January-April 1959 for the NS components. Earth current registrations for February 1959 are very distorted because of snowstorms, and were excluded from the analysis of both components. Fig. 4 shows the diurnal variation of earth currents at the Tiksi

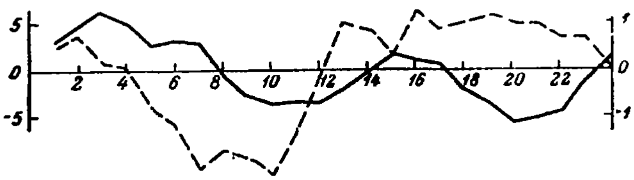

Fig. 4. Diurnal course of variations in the potential gradient of the earth currents for October-December 1958, January-April 1959. Solid line - latitudinal component; broken line - meridional component.

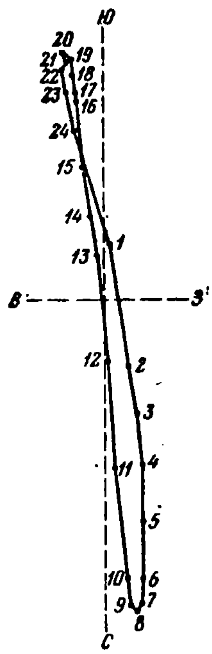

Fig. 5. Hodograph of the potential gradient for April 1959.

station for October-December 1958, January , March, and April 1959.

According to the monthly hodograms for November 1958-April 1959 (Fig. 5), it can be seen that the vector of the complete potential gradient has a predominantly meridional direction. The predominance of the meridional component over the latitudinal, the increase of the potential gradient in summer and its decrease in winter were also observable at the Fairbanks College station (Ref. 7).

Results

From an analysis of the data of the reduction of earth current recordings at Tiksi Bay for March 1958-April 1959, the following conclusions can be made.

1. In going away from the shore of the bay, the intensity of the earth currents decreases, i.e. the so-called coastal effect in earth currents takes place.

2. The meridional component is more intensive than the latitudinal and is displaced in phase relative to the latter.

3. The variable telluric field in the Tiksi region has elliptical polarization, the large axis of which is situated in a meridional direction.

4. A very good positive correlation exists between the earth-current disturbances and the magnetic field.

5. The seasonal variation of the disturbance maxima in the earth currents and that of polar aurorae are in good agreement according to photographic and radio-location observations.

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VIII. PRELIMINARY RESULTS OF THE EARTH CURRENT OBSERVATIONS AT THE BARENTSBURG STATION (Spitzbergen)

by

N. M. Nikitina

Observations of the earth currents at the Barentsburg Geophysical Station were conducted from 2 October 1957 through 30 June 1959 at rotation rates of 90 mm/hr and 30 mm/min. The station was situated in a valley 2 km wide composed of alluvial deposits of the river, and surrounded on all sides by mountains.

The earth-current installation was of the 4-electrode type. The NS (700 m) and EW (600 m) receiving lines were laid in the direction of the geographic meridian and the geographic parallel. In view of the fact that during the summer months the valley was crossed by many violent brooks it was decided to string part of the cable on poles. The overhead part of the NS line amounted to 400 meters, that of the EW - 300 meters. The remaining part of the cable was buried at a depth of about 20 cm. Holes two meters deep were dug for ground. Lead plate electrodes were packed in a mixture of coal, clay and salt.

The nearness of a mine is a cause of noise from power installations, both at slow and at fast recording. At slow recording, the noise has the form of splashed aimed at both components in one direction. On the fast registrations the interference has the character of successive impulses and overshoots. The noise has a well-expressed diurnal variation; it appears principally from 1600 to 0800 hr according to Moscow time, but in the period from 0800 to 1600 hr(during the day) it is almost never encountered. The noise occurs usually in groups in the course of several hours. The duration of a splash is 7-10 minutes. In winter the noise appears considerably less frequently than during the spring, summer or autumn. The cause of the noise is the movement of the electric trolley transport.

In a number of highspeed recordings "tremors" were noted: electrical pulsations with 1.8-2.0 sec periods, and amplitudes 1.5 mm for the NS line and 1.0 mm for the EW line, were superimposed on the recording. Sometimes the amplitude attained 2.5 mm for the NS and 1.5 mm for the EW lines. Having appeared, these pulsations lasted for several hours, and sometimes, with interruptions, for several days.

It was found that tremors arise during winds of up to 6 points with gusts up to 8 points in intensity. Such winds prevail in the winter time and have mainly a latitudinal direction. Tremors are caused by cable vibrations in the wind; this is confirmed by the coincidence of the vibration period of the cable spacings with the period of the tremors.

Operating Conditions of the Earth-Current Installations

The parameters of the installation for slow registration of the earth's electrical field are presented in Table 1. They were not changed during the two years the station was in operation.

Table 1

Line	Galvanometer φ				Panel ShchZT-1	
	N	T_g, sec	R_g, ohm	R_{kr}, ohm [1]	$R_{ballast}$, m/ohms	
					quiet operation	alert
NS	9264	9	240	1400-1500	2.7	7.9
EW	9450	8	270	1430-1500	2.4	7.0

During this same time the sensitivity at slow recording for the two components varied within the limits:

for quiet operation	NS 3.2-5.5 mv/km EW 3.3-6.0 mv/km
for alert operation	NS 12-15 mv/km EW 13-17 mv/km

In Table 2 are presented the parameters for the installation for rapid registration of the earth-current field from the opening of the station up to 9 March 1959.

Table 2

Line	D	$w_0\tau$	$R_{ballast}$, k/ohms	R_{sh}, k/ohms [1]	$R_{external}$, k/ohms
NS	0.8	24	400	4.7	3.5
EW	0.8	17	250	8.2	6.0

In March 1959 the operation of the installation for rapid registration was reorganized: ballast resistances were eliminated from the circuit in order to optimize the detection of pulsations with 2-4 sec

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[1] Exact meaning of these subscripts not determinable.

periods on the recording without the loss of pulsations with periods of 6-20 sec. On 23 March, operating conditions were established, involving parameters of the highspeed registration installation as shown in Table 3.

Table 3

Line	D	$w_0\tau$	s mef	R_{sh},[1] k/ohms	T_0, sec	R_g, ohms	R_{kr},[1] ohms	$R_{ballast}$, ohms	R, , ohms
NS	1	1.1	20	2.7	0.81	1660	2760	-	6000
EW	1	1.6	28	6.1	0.76	1670	6130	2000	3500

The resistance of the ground connection on the NS line reached 6000 ohms, and 3500 ohms on the EW line. To equalize the external parameters of the two components and also to coarsen somewhat the recording on the more sensitive eastern element, a 2 k/ohm ballast resistance was installed on the EW line. To eliminate the effect of this change, resistance boxes were included in the circuits of both lines. Resistance changes in both lines were compensated by the boxes in such a manner that the resistance of the lines as a whole remained unchanged.

Pulsations of the EW component were more intensive on the recording in comparison to the pulsations of the NS component. To equalize the sensitivity of the two lines, a potentiometric coarsening circuit was developed. The voltage was fed only to part of the by-pass. Operation under these conditions continued until the shutdown of the station. A shortcoming of the selected regime is its excessive sensitivity, as a result of which registration is undecipherable during disturbances.

Resistance of the Ground Connections

The resistance of the ground connection was measured periodically with a wheatstone bridge. The changes in the ground resistances during the entire operation of the station are shown in Fig. 1.

In winter the resistance values increase in comparison with the summer by a factor of 10-15. In summer the minimum value of the ground resistances for the NS lines was 400 ohms and for the EW lines was 350 ohms. In winter the maximum values were as much as:

in 1958 NS lines 5300 ohms
EW lines 1900 ohms

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[1] Exact meaning of these subscripts not determinable.

in 1959 NS lines 6600 ohms
EW lines 3700 ohms

The higher ground resistance values in the winter of 1959 in comparison with the winter of 1958 are explained by the fact that the winter of 1959 was more severe. The more intensive growth of resistance on the NS lines is clearly visible on the graph. This is explained apparently by the fact that the electrode on the south end of the line had become covered with water.

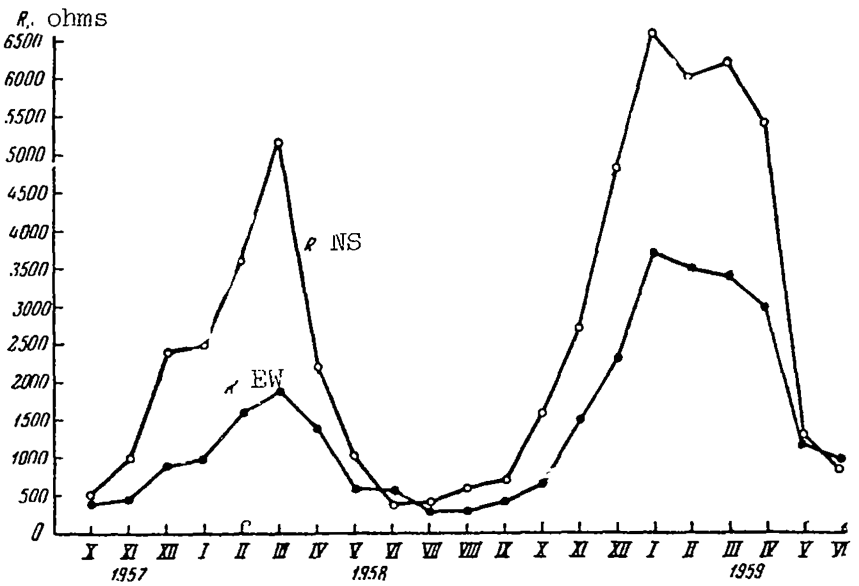

Fig. 1. Changes in the resistances of the ground connections (October 1957-June 1959).

Results of Observations

The earth-current field at the Barentsburg station is distinguished by a considerable activity. At pulsation amplitude values of up to 100 mv/km, the electrical field may be regarded as being quiet or weakly disturbed. Pulsation amplitudes during geoelectrical storms usually lie within the limits of 300-700 mv/km; the greatest amplitude values for the entire observation period reached 1.8 v/km for the NS element and 1.5 v/km for the EW element. Ordinarily the electrical field is more disturbed during the first half of the day, from 0300 to 1200 hr (Fig. 2). The maximum of the disturbances occurs during the period of 0500-0900 hr.

Fig. 3 shows the seasonal variation of the average monthly values for the hourly maximum amplitudes of both components of the electrical field during the entire observation period. The period between February

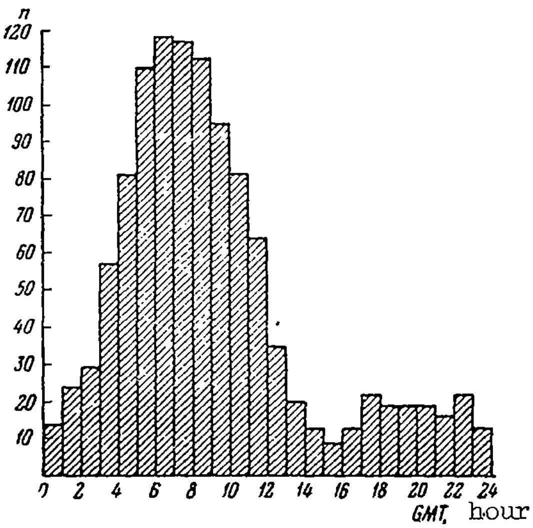

Fig. 2. Diurnal variation of the disturbed periods of the earth's electrical field (November 1957-May 1959).

and September 1958 was very disturbed; the greatest disturbance occurred in July 1958 when the average value of the hourly maximum amplitude reached 257 mv/km for the NS element and 227 mv/km for the EW element. The period between October and January was quiet both in 1957 and in 1958. In February 1959 an increase in disturbances began but not as significant a one as in 1958.

The most typical of the manifestations on recordings of earth currents in Barentsburg are long-period pulsations of irregular shape with periods of 3-5 minutes; frequently pulsations with a lesser period are superimposed on them. The detection of pulsation trains according to recordings at a single Arctic station is very difficult. Continuous

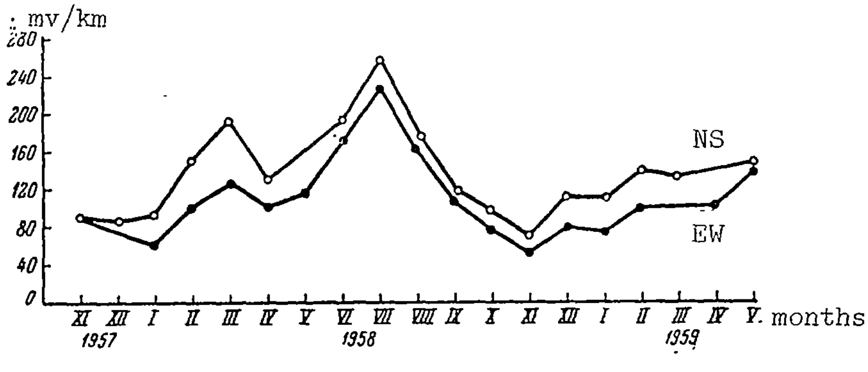

Fig. 3. Seasonal variation of the average monthly hourly maximum amplitudes of the earth's current field (November 1957-May 1959).

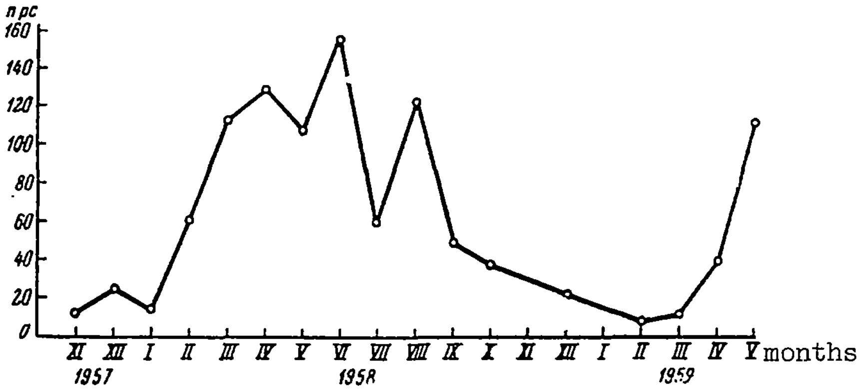

Fig. 4. Seasonal variation of continuous pulsations (November 1957-May 1959).

pulsations, beating-type pulsations, and bay-type disturbances are reliably separable according to the Barentsburg registrations.

Continuous pulsations. Continuous pulsations are frequently observed in the slow recording of earth currents. Their amplitudes lie within the limits of 15-300 mv/km; most frequently encountered are pulsations with amplitudes of 20-70 mv/km. The periods of the continuous pulsations are 20-40 sec. From Fig. 4 it can be seen that during the operation of the earth-current station, continuous pulsations were most often noted in February-September (maximum in June). In 1959 their number in April-May increased.

Continuous pulsations have a clearly expressed diurnal variation

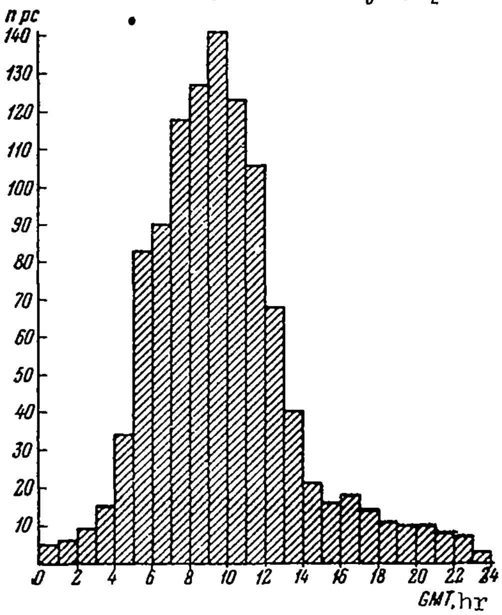

Fig. 5. Diurnal variation of the continuous pulsations (November 1957-May 1959).

(Fig. 5). They appear mainly during the first half of the day with the maximum at 0700-1200 hr.

Bay-type pulsations are observed in the slow recording of earth currents. They are seldom encountered, and principally in the first half of the day in the period of 2300-0900 hr Greenwich time. On the high-speed recordings they are accompanied by pulsations of irregular shape with periods of 5-20 sec.

Beat-type pulsations (pearls) are periodically observed in the rapid recording of the earth currents at Barentsburg. These are pulsations with 1-5 sec periods of regular sinusoidal form. From Fig. 6 it can be seen that the beats with a longer period (3-5 sec) occur in the first half of the day from 0300-1300 hr; their maximum occurs at 0800-0900 hr. Beats with periods of 1-2 sec are encountered principally at 0700-1100 and 1700-0100 hr (Greenwich time).

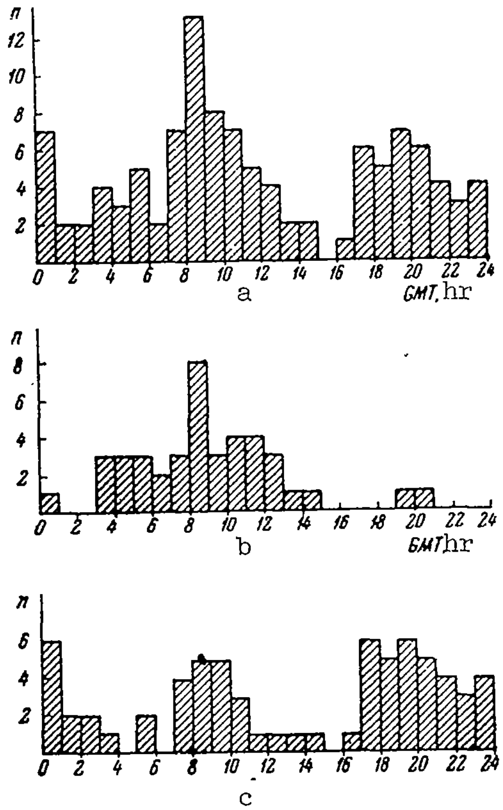

Fig. 6. Diurnal variation of beat-type pulsations (pearls) with periods of 1-5^s (a), 3-5^s (b), 0.7-2^s (c) (October 1957-May 1959).

The data presented on the SPP and the disturbances of the earth-current field are the first results of the analysis of observation materials obtained during the entire operation period of the Barentsburg station. In the future it is intended that the obtained material will be used to study the peculiarities of the behavior of the earth currents and the SPP of the electromagnetic field of the earth in the Arctic and Antarctic regions.

IX. GIGANTIC PULSATIONS IN THE SOVIET ARCTIC DURING THE 1935-1956 PERIOD

by

E. P. Zubareva, G. I. Korobkova, N. M. Nikitina and V. A. Troitskaya

Gigantic pulsations are short-period pulsations of the earth's magnetic field, typical apparently only for the region bordering the zone of polar aurorae. This characteristic peculiarity of the geographic distribution of the gigantic pulsations (GP) allows us to assume that the mechanism of excitation of these pulsations differs substantially from the excitation mechanism of other short-period pulsations, for example, that of the pt and pc types (as known, both of these types of pulsation are usually observable simultaneously over a vast territory). The study of GP is necessary, additionally, because in these pulsations are reflected processes that are typical of the most interesting and active (from the point of view of electromagnetic processes) polar region, of the upper layers of the atmosphere.

The regularities of the excitation of GP were studied chiefly on the basis of recordings of the magnetic field at stations situated in the northern part of the Scandinavian peninsula (Refs. 1-4). In the Soviet zone of the Arctic region, GP were not specially studied. In study of all the types of SPP in the Arctic region, they were combined into one group with complex harmonic pulsations (Ref. 5), and general regularities were derived for them.

The data set forth below were obtained as a result of the analysis of standard recordings of the magnetic field at the observatories of the Arctic and Antarctic Scientific Research Institute of the Main Administration of the Northern Sea Route (AANII). These data are in basic agreement with the characteristics of GP (diurnal and seasonal variations, distribution according to amplitude and period, etc.) presented in the works (Refs. 1-5).

A very interesting result of the investigation is the fact that the propagation of GP, evidently is restricted not only southwards of the polar auroralzone but also northwards of it. Thus, not one case of the excitation of typical intensive gigantic pulsations was observed in Tikhaya Bay for 20 years. Recordings of the magnetic field on the drifting stations SP-6 and SP-7 for 1956-1957, and also for the first 3 months of 1959 also attest to the absence of GP in the highest latitudes. The research results indicate that one of the basic requirements of the theory set forth in (Ref. 6), the simultaneous zonal excitation of GP, is valid only in individual cases. Nevertheless such cases exist, and this indicates that the excitation of GP can arise simultaneously in an interval of longitudes greater than 100°.

Initial Data

The research was carried out on the basis of standard magnetograms with a recording rate of 20 mm/hr, which were obtained at different periods between 1934 and 1956 at AANII stations and the polar stations of the Main Administration of the Northern Sea Route. Data from the following stations were used for the analysis: Dixon, Wellen, Matochkin Shar, Tiksi, Chelyuskin and Tikhaya Bay. Table 1 shows the years in which gigantic pulsations were observed at the stations enumerated above (even if only one case), and the years in which they were absent.

Table 1

Gigantic Pulsations in the Soviet Arctic Region

Station	Years																								
	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957
Dixon.......		+	+	+	+	+	+	+	+	+	+	-	+	+	-	-	-	-	-	-	+	+	-	-	-
Matochkin Shar....	-	+	-		+	+	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+	+	-	
Chelyuskin..		-	+	+	-	+	-	-	-	-	-	+	+	+	-	-	-	-	-	+	-	-	-	+	
Wellen......		-	+	+	+	+	+	+	+	+	-	+	+	+	-	-	-	-	-	-	-	+	+	-	
Tiksi.......														+	-	-	-	-	-	-	-	-	-	+	+
Tikhaya.....	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

+ indicates the presence of GP; - indicates the absence of GP; a blank indicates the absence of recordings for that year.

It must be emphasized that only the most typical cases were studied.

Fig. 1 shows the case of a gigantic pulsation registered simultaneously at two observatories - Dixon and Matochkin Shar - on 16 April 1939. In the article (Ref. 7), a rare case is presented of the simultaneous recording of GP (6 April 1959) in the magnetic field and in the earth-current field at a recording rate of 20 mm/hr and the simultaneous recording of the same pulsation at the high-speed rate (90 mm/hr).

Fig. 1. Example of a gigantic pulsation registered simultaneously at the Dixon (a) and Matochkin Shar (b) stations on 16 April 1939.

Basic Results

In the period studied, the greatest number of cases of gigantic pulsations were registered at the Dixon and Wellen stations (the geomagnetic latitude for Dixon is 63° and for Wellen is 61.8°)[1]. Analysis showed that the most probable periods for GP are 60 and 90 sec. This was also confirmed by recordings at other stations. A large part of the spectra of the periods at the Dixon station (Fig. 2) may be regarded as a series of harmonics with the lowest period equal to 60 sec (the values at 60, 90, 120 and 180 sec stand out on the graph). In addition to the 60 and 90 sec periods, other periods are also characteristic for the Wellen station, in particular T ~ 45 sec. Periods of 75 and 135 sec are characteristic for a number of stations.

The data obtained indicate that GP possibly have one or two fundamental periods, various harmonics of which are observable at specific stations depending on local conditions (Ref. 5). Their amplitudes usually fluctuate within the limits of several gamma to several tens of gamma. They attain their greatest values principally in the horizontal component.

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[1] A characteristic peculiarity of Wellen is the presence in the recordings of a large number of regular, small-period sinusoidal pulsations which we classed with GP.

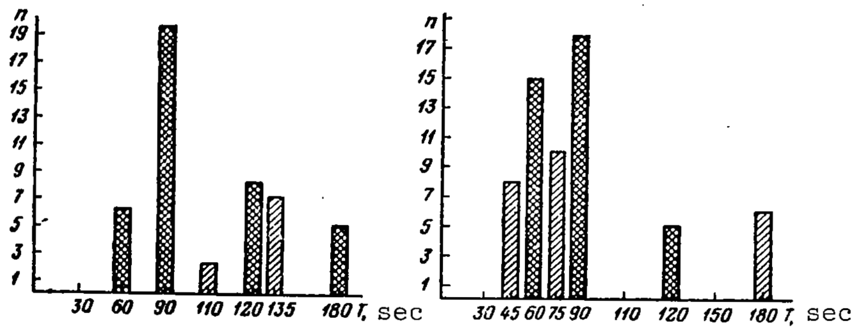

Fig. 2. Distribution of gigantic pulsations by period at the Dixon (a) and Wellen (b) stations.

Diurnal Variation of GP

In Fig. 3 is presented the diurnal variation of GP for the Wellen, Dixon and Matochkin Shar stations according to local time. As the graphs indicate, at the Dixon and Wellen stations GP arise principally during the first half of the day. The distribution of GP at these stations according to universal time shows their tendency to be excited principally from 2000-2200 to 0400-0600 hr.

Seasonal Variation of GP

The seasonal distribution of GP is presented in Fig. 4. The graph for Dixon (Fig. 4a) shows a clear growth in the number of cases of GP during the equinoxes, which is in complete agreement with the data obtained for Scandinavia.

At the Wellen station (Fig. 4b) the distribution is less indicative. It is possible that the inclusion of small-period sinusoidal pulsations in the statistics influenced the shape of the curve.

Therefore it is very probable that the distribution reflected the excitation regularities of two different types of pulsation.

A conception of the distribution of typical gigantic pulsations according years for the investigated period may be obtained from Table 1.

Geographic Distribution of GP

For theoretical study of the excitation mechanism of GP, it is important to know the regularities of the geographical distribution of

Table 2

Cases of the Simultaneous Excitation of Gigantic Pulsations at Several Polar and Middle-Latitude Stations

Station	Lat.N.	Long.	Greenwich Time		Period sec	Amplitude, gamma		
			Beginning	End		D	H	Z
				9 June 1937				
Maytun[1]	32°24'	198°18'	0330	0600	60	--	1.1	--
Srednikan	53 12	210 30	0330	0600	60	--	2.8-2.9	--
Dixon	63 00	161 30	0350	0600	60	4	10.4	--
Wellen	61 48	23 70	0100	0200	60	0.8	1.6	--
				18 April 1938				
Maytun	32°24'	198°18'	0000	0700	100	--	1.3	--
Srednikan	53 12	210 30	0200	0500	100	0.5	2.8	--
Nizhnedevitsk	46 54	119 36	0200	0600	100		weak trace	
Dixon	63 00	161 30	0115	0330	135	8	10.4	10.6
Sodankyulya[1]	63 42	12 00	0207	0525	113		no data	
				23 May 1938				
Srednikan	53°12'	210°30'	0830	0930	150	--	2.8-2.9	--
Nizhnedevitsk	46 54	119 36	0800	0900			weak trace	
Dixon	63 00	161 30	0300	0400	150	5	10.4	5.3
Matochkin Shar	64 48	146 30	0800	0900	130	11.5	21.3	14.0
				27 July 1938				
Maytun	32°24'	198°18'	0200	0800	120	--	1.2	--
Dixon	63 00	161 30	0250	0500	108	10.8	20.8	10.6
Wellen	61 48	23 70	0000	0100	72	1.1	2.7	5.2
Matochkin Shar	64 48	146 30	0410	0530	90	4.4	14.2	--
				16 April 1939				
Maytun	32°24'	198°18'	0000	0700			weak trace	
Srednikan	53 12	210 30	0000	0700	100	--	2.9	--
Nizhnedevitsk	46 54	119 36	0400	0700			weak trace	
Dixon	63 00	161 30	0400	0700	120	18	26	11
Matochkin Shar	64 48	146 30	0500	0730	180	11.2	17.5	6.0

[1] Exact spelling is in doubt. As given here, it is simply transliterated.

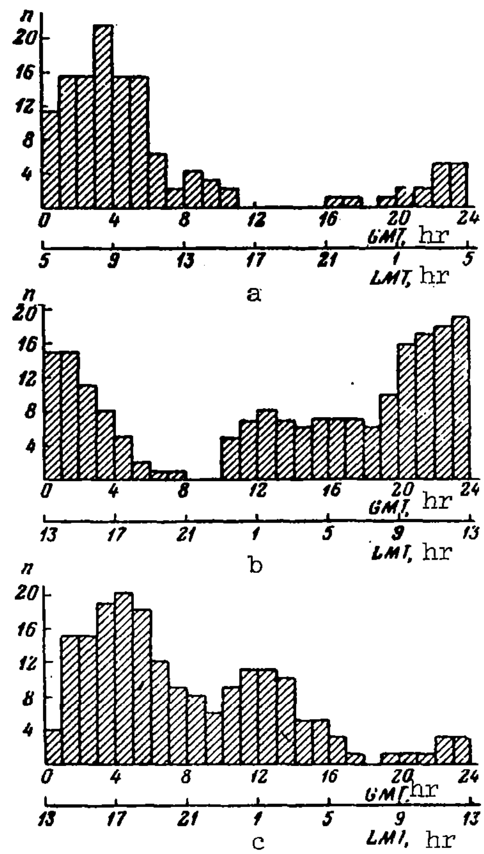

Fig. 3. Diurnal variation of gigantic pulsations according to local time at the Dixon (a), Wellen (b), and Matochkin Shar (c) stations.

GP and, above all, the characteristics of their zonal excitation. The data available from a number of stations allowed the problem of the excitation of GP over a large latitudinal interval to be examined for the first time.

Comparison of all the cases observed showed that, with the existing recording parameters, GP are observable simultaneously at several stations only in a small number of cases (Tables 2 and 3). Nevertheless a number of GP were registered simultaneously at Dixon and Wellen, i.e. in a latitudinal interval of about 110°. It is very probable that to study the geographical distribution of GP, the recording parameters must be brought into special agreement with previous

Table 3

Gigantic Pulsations Registered Simultaneously and at Various Hours at Several Polar Stations

Station	Date	Type	Time, GMT		Duration, min[1]	Period, sec	D, H, Z	Amplitude, gamma
			Begin.	End				
Dixon	12 Mar 34	A	2030	2230	80	90	D	4
Matochkin Shar	12 Mar 34	A	2100	2210	70	90	D	1.65
Dixon	9 Jun 37	B	0350	0600	130	60	D	4.0
							H	10.4
							Z	--
Wellen	9 Jun 37	A	0100	0200	60	60	D	0.8
							H	1.6
							Z	--
Dixon	23 May 38	A	0300	0400	60	150	D	5
							H	10.4
							Z	5.3
Matochkin Shar	23 May 38	B	0800	0900	60	130	D	11.1
							H	21.3
							Z	14.0
Wellen	27 Jul 38	A	0250	0500	130	108	D	10.8
							H	20.8
							Z	10.6
Dixon	27 Jul 38	A	0410	0530	80	90	D	4.4
							H	14.2
							Z	15.0
Matochkin Shar	27 Jul 38	A	0000	0100	60	72	D	1.1
							H	2.7
							Z	5.2
Dixon	16 Apr 39	B	0400	0700	180	120	D	18
							H	26
							Z	11
Matochkin Shar	16 Apr 39	B	0500	0730	150	180	D	11.2
							H	17.5
							Z	6.0

[1] Original text has in hours and minutes. Converted to minutes for brevity.

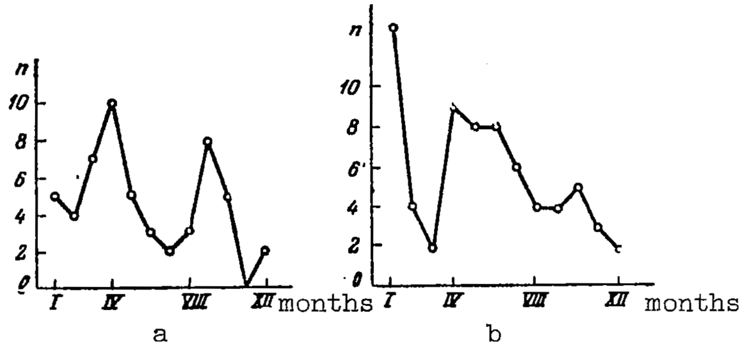

Fig. 4. Seasonal variation of GP at the Dixon (a) and Wellen (b) stations.

consideration of the distribution of GP according to amplitude at the various stations.

It is interesting to note that frequently GP are observed at various stations on adjacent days at about the same time. Sometimes the excitation of GP occurs on a certain day at different but close hours, at different stations. In this connection in a majority of cases they first appear at the easternmost station and later at a more western station. (Ref. 5)

All of the examined cases confirm the conclusion that GP are a disturbance of the earth's electromagnetic field, typical for the polar auroral zone and rapidly alternating to the south and to the north of it.

The obtained distribution of GP by period may be interpreted as a confirmation of the existence of a fundamental period for this type of pulsations (Ref. 6). The analysis carried out allowed cases of GP excitation to be observed over a large latitudinal interval (about 100°). However, these cases are rare and the problem of the peculiarities of the zonal excitation of GP apparently requires special observations.

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X. ON THE NONPERPENDICULARITY OF THE E AND H VARIATION VECTORS OF THE ELECTROMAGNETIC FIELD OF THE EARTH

by O. M. Barsukov and K. Yu. Zybin

Study of the time variations in the direction of the components of the earth's electromagnetic field is closely connected with the question of the geological structure of the region in which observations are being conducted. Earlier (Refs. 1, 2) it was shown that the horizontal component of the electrical field strength E has a predominant direction of pulsations that is stable at each observation point. During a 24-hour period this direction has a diurnal course that is definite for the given point, but is different for observation points located relatively close together.

On the other hand, it is known that a portion of the short-period variations arise simultaneously over extensive territories, preserving nevertheless the shape of the pulsations. Consequently, the cause determining the direction of the pulsations and the form of the diurnal course of the directions is, apparently, the heterogeneity of the geological structure at the observation points. The nonperpendicularity of the directions of the horizontal magnetic and electrical components of short-period pulsations, that is likewise observable at a number of points, attests to this.

The vectors of electrical intensity $\vec{E}$ and the vectors of current density $\vec{j}$ coincide in direction on the surface of a homogeneous or horizontally stratified semispace, while the horizontal magnetic force vector $\vec{H}$ is perpendicular to them. Generally, these conditions are disturbed on the surface of a horizontally heterogeneous semispace.

Let us examine a horizontally anisotropic medium whose conductivity is describable by a tensor with main axes of γ_{11}, γ_{22}, and γ_{33}. Let us select the coordinate axes x, y, and z so that the direction of the z axis coincides with direction of the main tensor axis γ_{33}, and the x axis is inclined at the angle φ in the direction of γ_{11}. The conductivity tensor is transformed into the form:

$$\gamma = \begin{vmatrix} \gamma_{11}\cos^2\varphi + \gamma_{22}\sin^2\varphi & (\gamma_{22} - \gamma_{11})\sin\varphi\cos\varphi & 0 \\ (\gamma_{22} - \gamma_{11})\sin\varphi\cos\varphi & \gamma_{11}\sin^2\varphi + \gamma_{22}\cos^2\varphi & 0 \\ 0 & 0 & \gamma_{33} \end{vmatrix}.$$

Let the field E on the surface be polarized linearly in the direction of x, i.e., $E_y = 0$; $E_z = 0$. Then we have:

$$j_x = E_x(\gamma_{11}\cos^2\varphi + \gamma_{22}\sin^2\varphi);$$
$$j_y = E_x(\gamma_{22}\sin\varphi\cos\varphi - \gamma_{11}\sin\varphi\cos\varphi).$$

Introducing the designations α as the angle between $\vec{E}$ and $\vec{j}$, and $\eta = \frac{\gamma_{22}}{\gamma_{11}}$, we obtain:

$$\operatorname{tg}\alpha = \frac{j_y}{j_x} = \frac{(\eta - 1)\operatorname{tg}\varphi}{1 + \eta\operatorname{tg}^2\varphi}.$$

Thus, in an anisotropic semispace the directions of $\vec{j}$ and $\vec{E}$ do not in the general case coincide with one another; this causes nonperpendicularity of the horizontal components $\vec{E}$ and $\vec{H}$. The diurnal courses of the directions of $\vec{E}$ and $\vec{H}$ may fail to coincide among themselves even with respect to shape, since $\tan\alpha = f(\eta, \varphi)$.

The difference of the azimuths of $\vec{E}$ and $\vec{j}$ (or $\vec{H}$) may be estimated, knowing η and φ--the angle between the direction $\vec{E}$ and the main conductivity-tensor axis γ_{11}. The maximum deviation of the direction of $\vec{E}$ from the direction of $\vec{j}$ at a given η is estimated from the condition $\frac{\partial(\operatorname{tg}\alpha)}{\partial(\operatorname{tg}\varphi)} = 0$, i.e., when

$$\operatorname{tg}^2\varphi = \frac{1}{\eta}; \qquad \operatorname{tg}_{max}\alpha = \frac{\eta - 1}{2\sqrt{\eta}}$$

In the limiting case of $\eta \to 0, \alpha \to \frac{\pi}{2}$, the magnetic and electrical vectors are parallel.

Under real conditions there can be more complex media, therefore the considerations set forth should be regarded as an approximation.

In order to estimate the difference of the azimuths of the variations of $\vec{E}$ and $\vec{H}$, 24-hour magnetic and electrical recordings at the Lovozero and Borok stations were processed. Electrometric investigations by the VEZ[1] method were carried out at these stations at the same time.

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[1] expansion unknown

The predominant directions of vectors $\vec{E}$ and $\vec{H}$ and their diurnal course were determined for Lovozero by the method proposed in the work (Ref. 1). The magnetic azimuth of the predominant direction of the vector of the earth-current variations is equal to 67.3°.[1] The azimuth of the magnetic variations is equal to $+31.8^\circ$ which gives a deviation of $9\pm1^\circ$ from perpendicularity (Figure 1). Here the diurnal course of the predominant direction $\vec{H}$ is analogous to the diurnal course of the predominant direction of $\vec{E}$.

In accordance with the formula for tan α, such an angle ($\alpha = 9^\circ$), can be due to the medium with a ratio of the chief anistropy axes amounting to $\eta = 1.4$. Electrometric investigations in the region of the Lovozero station permitted us to interpret a three-layered cross-section

h_1 = m; p_1 = 1200-1500 ohms·m;
h_2 = m; p_2 = 300- 500 ohms·m;
$p_3 = \infty$.

Data from circular investigations conducted at 4 points near the electrode A (electrode B is at infinity), at 8 azimuths through 45° for each point, were subjected to analysis for determining the ellipse of the apparent specific resistance.

A vector diagram in terms of polar coordinates was constructed for the fixed spacing AO, the length of the vector being the apparent specific resistance, and the polar angle β being the azimuth of the installation. Let us assume that the ends of the vectors are situated on a closed curve, an ellipse, with certain random deviations. The equation of the ellipse in polar coordinates, with the polar axis not coinciding with the axis of the ellipse a for the angle δ has the form:

$$\frac{1}{\rho^2} = \frac{\cos^2(\beta - \delta)}{a^2} + \frac{\sin^2(\beta - \delta)}{b^2}.$$

Substituting

$$a = \frac{1}{a_1}, \qquad b = \frac{1}{b_1},$$

[1] In the work (Ref. 1) the azimuth of $\vec{E}$ for Lovozero was determined with a constant error caused by the inaccurately determined parameters of the installation.

it is not difficult to obtain the expression

$$— = (a_1^2\cos^2\delta + b_1^2\sin^2\delta) + \sin^2\beta\cos 2\delta\,(b_1^2 - a_1^2) + \frac{1}{2}\sin 2\beta\sin 2\delta\,(a_1^2 - b_1^2),$$

which after simple transformations is reduced to the form

$$y = B_0 + B_1 x + B_2 z,$$

where

$$y = \frac{1}{\rho^2};\qquad x = \sin^2\beta;\qquad z = \sin 2\beta;$$

$$B_0 = a_1^2\cos^2\delta + b_1^2\sin\delta;$$

$$B_1 = (b_1^2 - a_1^2)\cos 2\delta$$

$$B_2 = (a_1^2 - b_1^2)\sin\delta\cdot\cos\delta.$$

Assuming that the azimuth β was measured without error, and that the deviations of the ends of the vectors from the ellipse took place

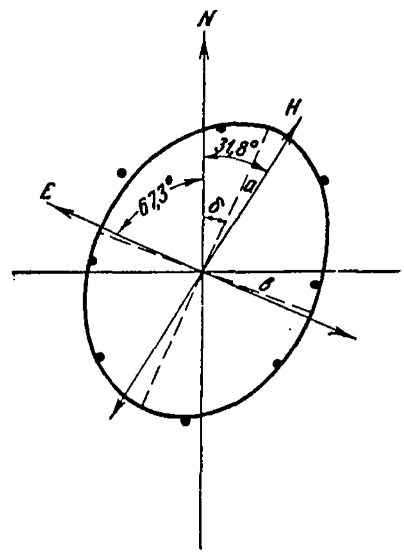

Figure 1. Ellipse of anisotropy and the predominant directions of E and H at the Lovozero station.

as a result of random errors in the measurement of ρ, the values of B_0, B_1, and B_2 can be determined by the least squares methods (Ref. 3) with the aid of determinants.

$$B_0 = \frac{\begin{vmatrix} \sum y & \sum x & \sum z \\ \sum xy & \sum x^2 & \sum xz \\ \sum zy & \sum xz & \sum z^2 \end{vmatrix}}{D}, \qquad B_1 = \frac{\begin{vmatrix} n & \sum y & \sum z \\ \sum x & \sum xy & \sum xz \\ \sum z & \sum zy & \sum z^2 \end{vmatrix}}{D},$$

$$B_2 = \frac{\begin{vmatrix} n & \sum x & \sum y \\ \sum x & \sum x^2 & \sum xy \\ \sum z & \sum xz & \sum zy \end{vmatrix}}{D}, \qquad D = \begin{vmatrix} n & \sum x & \sum z \\ \sum x & \sum x^2 & \sum xz \\ \sum z & \sum xz & \sum z^2 \end{vmatrix},$$

where n is the number of azimuths.

Thus, we finally obtain:

$$\frac{a^2}{b^2} = \frac{B_0 + B_1 - B_2 \operatorname{tg} \delta}{B_0 + B_2 \operatorname{tg} \delta}, \qquad \operatorname{tg} 2\delta = -2\frac{B_0}{B_1},$$

where δ is the angle of the inclination of axis a of the ellipse in the direction of $\beta = 0$.

Figure 1 shows the computed anisotropy ellipse. The points represent the values of the measured ρ.

As a result of processing of the results of the circular investigations by the method set forth above, the ellipse axis ratios a/b and the angles δ were obtained (for each 8 spacings at all 4 observation points).

Analysis of these data indicates the following.

1. The angles δ change sharply both in the transition from one point to another, and in the transition from one fixed spacing to another.

2. With a fixed spacing, the ellipse axis ratios for all observation points change within the limits of 15-20 percent.

3. At all observation points when the spacing AO = 110 m, the greatest ellipse axis ratio is observed, it being equal to 1.25-1.56. Further increase of the spacing did not substantially change this ratio.

Such anisotropy, in accordance with the formula for tan α, provides for a deviation of the direction of $\vec{j}$ from the direction of $\vec{E}$ at a maximum angle of $6\text{-}12^{\circ}$.

The azimuths of the predominant directions of the variation vectors $\vec{E}$ and $\vec{H}$, equal respectively to $+57.1^{\circ}$ and -35.2° (Figure 2) have been determined at the Borok station. The diurnal course of the direction of the variations of the horizontal magnetic vector was obtained by two different methods.

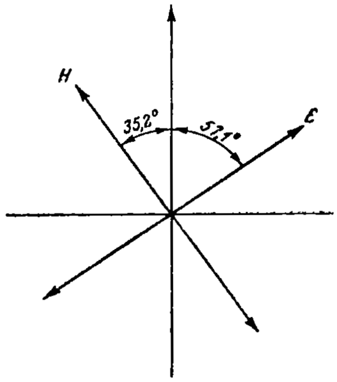

Figure 2. Predominant directions of $\vec{E}$ and $\vec{H}$ at the Borok station.

1. According to the maximum hourly amplitudes. The values of the maximum recording amplitude (in gammas) were taken from the magnetograms for each hour separately for the components H_x and H_y. The ratios of these values were averaged for all days for a given hour. In Figure 3a the values of the angles, computed as the arc tan $\left(\overline{\frac{H_x}{H_y}}\right) = \frac{\pi}{2} - \theta$, where θ is the magnetic azimuth, are plotted on the ordinate axis; Greenwich time (GMT) is plotted on the abscissa axis.

2. According to the directions of the large axes of the ellipses of polarization (Ref. 4). For each hour of observation, diagrams were constructed of the behavior of the horizontal vector of the variations for one or several characteristic pulsations with a period of from 2 to 10 minutes. The obtained vector diagrams were approximated as ellipses. The directions of the large axes of the ellipses were taken as the directions of the pulsations of $\vec{H}$. The azimuths of these directions, θ, were averaged for all the days for a given hour. (Figure 3b).

The diurnal course of the directions of the variations of the electrical vector $\vec{E}$ was obtained according to the maximum hourly amplitude (Figure 3c).

Electrometric investigations by the cross VEZ method in the region of the Borok station permitted a three-layered cross-section to be interpreted:

$h_1 = 10$ m; $\rho_1 = 180$ ohms·m;
$h_2 = 30$ m; $\rho_2 = 45$ ohms·m;
$\rho_3 = 11$ ohms·m.

No horizontal anisotropy was observed.

As can be seen from Figures 2 and 3, the predominant direction of the variation vectors $\vec{E}$ and $\vec{H}$ differ by 90° within the limits of error (evaluation of the reliability is presented below). The perpendicularity of $\vec{E}$ and $\vec{H}$ is preserved in the diurnal course of the directions of both vectors. It should be noted that the well-expressed diurnal courses of the directions coincide with one another in spite of the fact that they were obtained by substantially different methods.

Since neither the deviation from perpendicularity nor the amplitudes of the diurnal courses exceed several degrees, the reliability of the results presented was evaluated according to the method of confidence intervals (Ref. 5).

As was indicated earlier, the angle determinable by the expression following is taken as the value which characterizes the direction of the pulsations of the magnetic variation vector for a given hour:

$$\overline{\mathrm{tg}}\left(\frac{\pi}{2} - \theta_i\right) = \frac{1}{n} \sum_{m=1}^{n} \left(\frac{H_x}{H_y}\right)_{i,m},$$

where n is the number of days considered in the analysis, and i is the number of the hour. Let us suppose that the deviation of the ratios H_x/H_y from the average is random, and that the measured ratios are of equal accuracy. One can find the interval I, which includes the values of the true tangent with a definite probability (reliability) of P.

$$I = \overline{\mathrm{tg}}\left(\frac{\pi}{2} - \theta_i\right) \pm \frac{cS}{\sqrt{n}},$$

where c is determined from Student's t-distribution tables on the basis of given reliability P and the number of degrees of freedom $k = n - 1$, and the estimate for the standard of error is:

$$S = \sqrt{\frac{1}{n-1}\left\{\sum_{m=1}^{n}\left(\frac{H_x}{H_y}\right)^2 - n\left[\overline{\mathrm{tg}}\left(\frac{\pi}{2} - \theta_i\right)\right]^2\right\}}$$

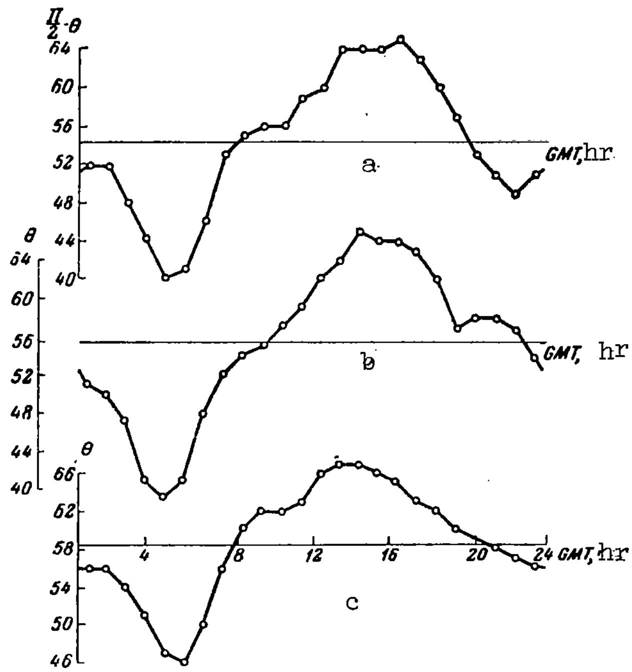

Figure 3. Diurnal course of azimuths at the Borok station.

a - H according to maximum aplitudes; b - H according to the large axes of the polarization ellipses; c - E according to maximum amplitudes.

The reliability of the value of the azimuth of electrical variations was estimated in an analogous manner.

At a high probability, equal to 99 per cent, the deviation of the azimuth from the average value for the entire time interval involved in the analysis does not exceed $\pm 1^{\circ}$ either for $\vec{E}$ or for $\vec{H}$. Thus the predominant directions of the azimuths of $\vec{E}$ and $\vec{H}$ have a stable character. The angle between the vectors of the variations of E and H at the Borok station was equal to $92.3 \pm 2^{\circ}$, and was equal to $-99.1 \pm 2^{\circ}$ at the Lovozero station.

In addition to this, an estimate of reliability for the Borok station was also made for each hourly value of the diurnal course of the azimuths. At a high probability, equal to 99 per cent, the deviation of the azimuths from the average for a given hour does not exceed $\pm 4^{\circ}$

either for $\vec{E}$ or for $\vec{H}$. The amplitude of the diurnal course of the directions, on the other hand, attains 20°.

Thus, investigations at the Lovozero and Borok stations indicate that the nonperpendicularity of the variation vectors of E and H can be explained by electrical heterogeneity (anisotropy) of the rocks at some depth under the surface at the observation points.

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XI. BEAT-TYPE PULSATIONS (PEARLS) IN THE EARTH'S ELECTROMAGNETIC FIELD ($T \sim 1$-4 sec)

by V. A. Troitskaya

Beat-type pulsations with periods in the order of 1-4 sec comprise a characteristic small-period class of disturbances of the earth's electromagnetic field. These pulsations can arise both in the form of individual bursts with a duration of 1-2 min, and in the form of long (tens of minutes) series of pulsations. A series of beat-type pulsations resemble a string of pearls, hence they are called "pearls" (Figure 1).

The first data on these pulsations were obtained on the basis of earth-current recordings at two Central Asian stations in 1952-1953. To the extent of the author's knowledge, no systematic study of the beat-type pulsations with periods of 1-4 sec on the basis of recordings of the magnetic field has been carried out. This is explained principally by the fact that their amplitude is very small[1] (as a rule, thousandths, hundredths and tenths of a gamma at the various stations), and cases of excitation are relatively rare. The systematic study of pearls at an extensive network of stations began during the IGY.

Beat-type pulsations are registered both on quiet and on disturbed days. Furthermore, during large magnetic storms pearls are as a rule observable simultaneously over a vast territory including the Arctic, the middle-latitude, and the Antarctic regions. On quiet days the size of the territory in which these pulsations are simultaneously observable may vary. Sometimes a splash of beat-type pulsations is observed simultaneously only at a number of Arctic stations, and sometimes simultaneously in the Arctic region, the middle latitudes, and even in Antarctica. In some cases the pulsations are observable only at one station but can also be traced at some specific group of middle-latitude or polar stations.

The study of beat-type pulsations is of great interest, since already in the very initial stage of their investigation a direct relationship was observed between their excitation in the course of magnetic storms and the occurrence of phenomena in the upper atmosphere. Thus, in the largest magnetic storms the emergence of a series of pearls of

[1] The amplitude of the beat-type pulsations in the earth's magnetic field was estimated on the basis of individual cases of their simultaneous recording at earth-current installations (24-hour recordings) and at highly sensitive fluxometric installations designed by A. G. Kalashnikov of (sliding recording).

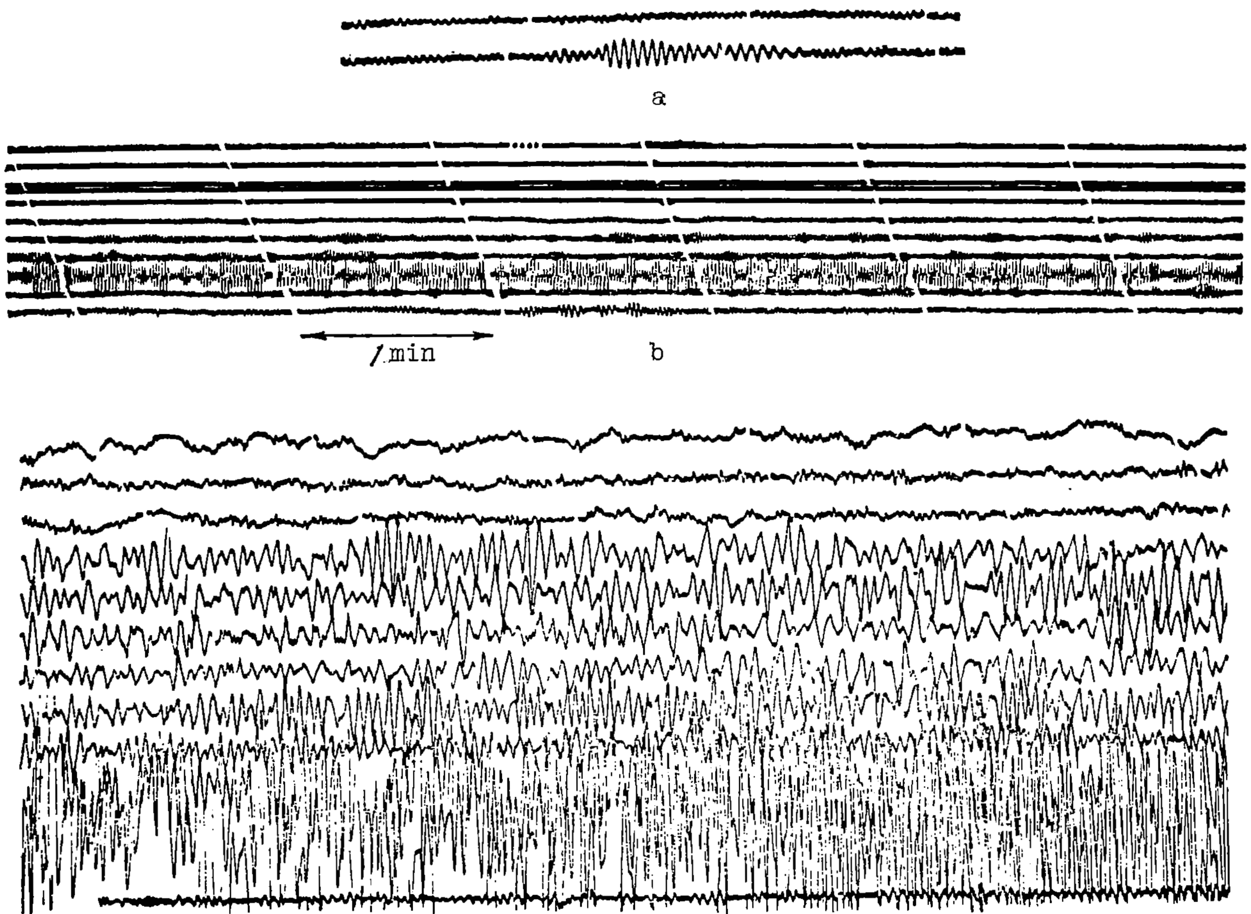

Figure 1. Examples of pearl-type pulsations.
a - typical bursts of pulsations (Hayes Island, 20 February 1958); b - a series of pulsations (Alma-Ata); c - pearls during a magnetic storm (Ashkhabad).

differing periods precedes or accompanies the propagation of polar aurorae into the low latitudes, as well as a sharp drop in the critical frequencies of the F2 layer, diffuseness, and sometimes periods of complete absorption in the ionosphere (Ref. 1).

In a number of cases, there was noted a coincidence of the excitation of pearl-type pulsations in the course of magnetic storms with splashes of roentgen radiation in the stratosphere.[1]

The study of the geographic distribution of these pulsations and their dependence on local time compels one to assume that regularities of the excitation of pearls are influenced both by world time and by universal time. Their source has, apparently, an extra-ionospheric origin.

Preliminary results of the research indicate that the conditions of excitation of pearls in the Arctic region and in the middle latitudes vary somewhat. In the Arctic region individual splashes of pulsations principally with a large period (4-6 sec) are noted, whereas in the middle latitudes long series of pulsations with a smaller period (2-4 sec) are frequently observed. In the case of simultaneous excitation, the period of these pulsations in the polar caps and in the middle latitudes are as a rule identical.

Initial Data

Study of the beat-type pulsations during the IGY was carried out on the basis of ultrahigh-speed round-the-clock recordings of earth currents with a rate of 30 mm/min. The basic technical specifications of these installations are presented in the works (Refs. 2, 3). Such installations were set up at the entire network of earth-current stations of the Soviet Union, including the Arctic and Antarctic regions (see Table).

The recordings from two Central Asian stations (Alma-Ata Garm) for 1952-1953 and from Yuzhno-Sakhalinsk for the first half of September 1952 were also used in the research. It should be noted that the coarsening of installation sensitivity, effected from time to time at some of the stations, resulted in the loss of a number of instances of beats.

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[1] There has recently been noted a coincidence of the moments of arrival in the stratosphere of protons with energies of 10-100 mev, generated during violent solar eruptions, with moments of the excitation of typical pearls in the polar latitudes.

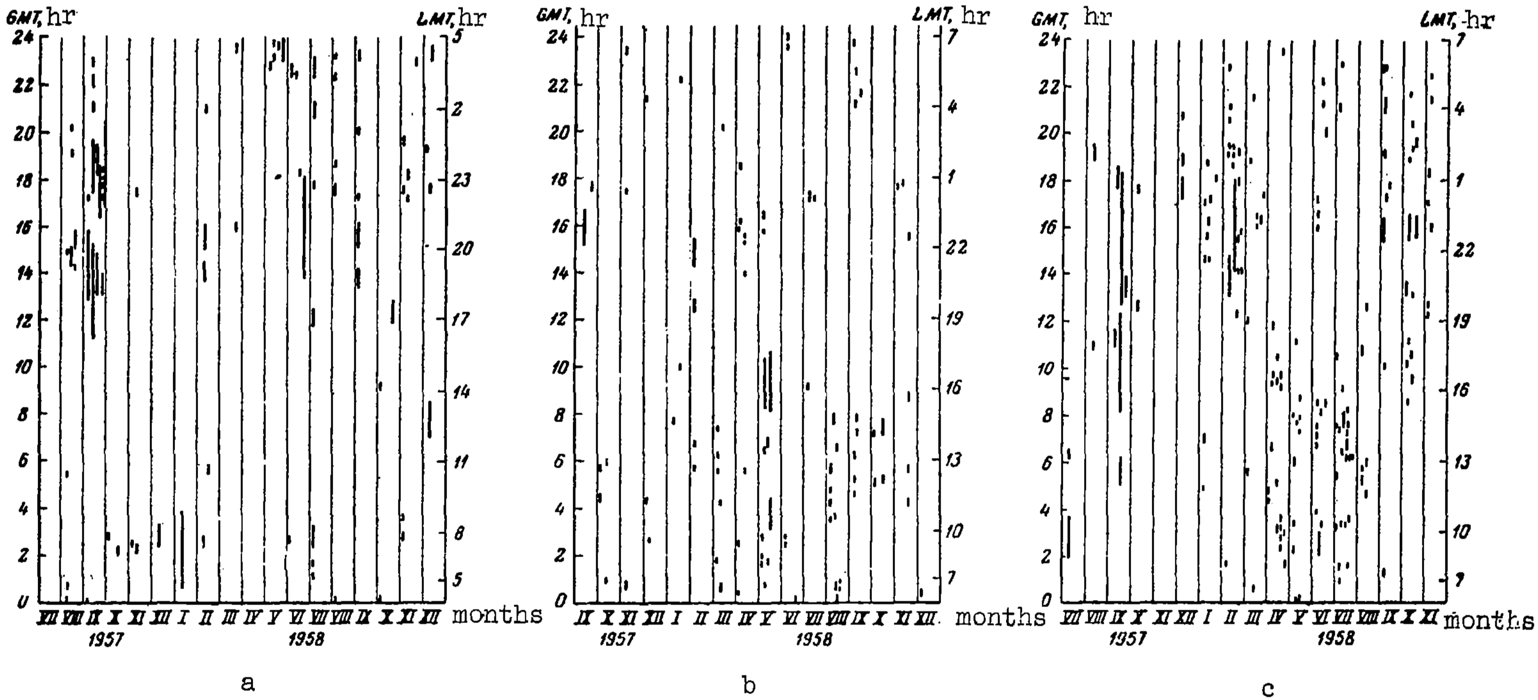

Figure 2. Distribution of pearls according to hours of the day, months and year for the stations:
a - Alma-Ata; b - Chelyuskin (Arctic); c - Oazis (Antarctica).

Table

Station	Latitude	Longitude	Time of Observation	No. of cases of pearls
Hayes Island (Tikhaya Bay)	70°54'N.	156°29'	Dec. 1957-Dec. 1958	66
Barentsburg (Piramida)	74 27 "	132 56	Oct. 1957-Jul. 1958	96
Chelyuskin	65 58 "	176 24	Sep. 1957-Dec. 1958	87
Lovozero	62 45 "	127 18	Jul. 1957-Dec. 1958	44
Oazis	77 43 S.	159 53	Jul. 1957-Nov. 1958	156
Mirnyy*	77 00 "	146 30	Jul. 1957-Dec. 1958	89
Borok	52 53 N.	123 20	Jul. 1957-Dec. 1958	81
Shatsk	48 43 "	123 42	Oct. 1957-Dec. 1958	24
Petropavlovsk-Kamchatskiy**	44 24 "	218 14	Jul. 1957-Dec. 1958	18
Yuzhno-Sakhalinsk	40 24 "	204 15	Feb. 1958-Dec. 1958	26
L'vov	47 00 "	104 09	Jul. 1957-Mar. 1958	12
Alushta	40 56 "	113 36	Jul. 1957-Nov. 1958	26
Alma-Ata	33 10 "	151 03	Jul. 1957-Dec. 1958	81
Ashkhabad	30 36 "	133 30	Jul. 1957-Dec. 1958	34

* The great difference in the number of cases of pearls registered at the Mirnyy and Oazis stations is explained by the fact that many recordings at Mirnyy for 1958 were defective.

** Processing of high-speed recordings at Petropavlovsk-Kamchatskiy was hindered by frequent noise.

Research Results

Description and Basic Characteristics of Pearls. Pearl-type pulsations constitute a splash or a series of pulsations wherein the same period is usually preserved during a given excitation cycle.[1]

Characteristic of this type of pulsation is an explicitly expressed amplitude modulation that frequently tunes to beats. A tendency was

[1] In the course of large magnetic storms, pearls of one period are replaced by pearls of another period, as a rule a lower one (Ref. 1).

noted for a series of pearls to be repeated on adjacent days at approximately the same time. The pulsation periods in such a case may vary.

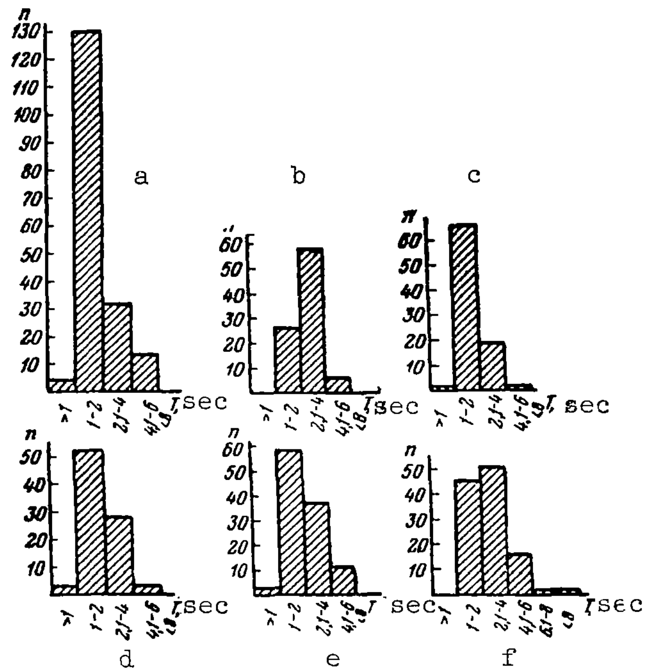

Figure 3. Distribution of pearls by periods for the stations: a - Oazis; b - Hayes Island; c - Alma-Ata; d - Borok; e - Piramida; f - Chelyuskin.

In Figure 2 graphs are presented which illustrate the character of the excitation of these pulsations, their duration, and their distribution according to the hours of the day and by months for the investigated period (1957-1958). The distributions for 3 stations are presented: middle-latitude (Alma-Ata), Arctic (Chelyuskin) and Antarctic (Oazis). The graphs indicate a predominance of short bursts of pulsations in the Arctic region, a large number of pulsation series in the middle latitudes, and a mixed pattern in Antarctica.

Pearls have a sharply expressed spectral distribution. Predominantly, their periods are equal to 1-4 sec. At 2 Arctic stations, Hayes and Chelyuskin, pulsations with a large period (2-4 sec) predominate. Figure 3 shows the distribution of pearls according to period for the Oazis, Borok, Alma-Ata, Piramida, Hayes, and Chelyuskin stations. The distribution of pearls by period for the other stations has an analogous character. The graphs show that pearls with periods greater than 4 sec are very rare and are noted chiefly at the Arctic stations. They are also found in the initial phase of intervals of pulsations diminishing by period (PDP = Russian KUP) in the course of magnetic storms (Ref. 1), when individual bursts of pulsations with periods of 5-10 sec arise. On quiet days, pearls with periods in excess of 5 sec practically do not occur. Pearls with periods of less than one second occur at times in recordings both on quiet days and on disturbed ones.

The amplitude of pearls for the middle latitude stations on quiet days amounts to hundredths and tenths of a millivolt per kilometer, and on days with storms reaches several millivolts per kilometer. At the polar stations, the amplitude of pearls is usually in the order of several millivolts per kilometer.

On disturbed days it reaches ten or even twenty or thirty millivolts per kilometer. Several cases of beats registered on a fluxometric installation at the Borok and Lovozero stations have indicated that the amplitude of these pulsations in the magnetic field is in the order of thousandths and hundredths of a gamma.

Thus, for the study of these pulsations in the earth's magnetic field in the middle latitudes, registration must be conducted with a sensitivity of not less than 0.001 gamma for Z and at a rate which permits the satisfactory resolution of pulsation periods of 1-4 sec (i.e. not less than 20-30 mm/min). Since cases of excitation of these pulsations are comparatively rare, only round-the-clock registration is expedient and not a sliding recording graph.

Diurnal Course of Pearl-Type Pulsations. The largest amount of data on pearl-type pulsations at our disposal was from the Alma-Ata station. Round-the-clock observations at a rapid recording rate (60 and 30 mm/min) were conducted at this station for several years before the IGY. The peculiarities of the diurnal course of pearl-type pulsations are most clearly apparent in the distribution (Figure 4) constructed for this station on the basis of material obtained in the 1952-1953 and 1957-1958 periods.

The distribution of pearls at the Ashkhabad station has been presented in the work (Ref. 4). The graph indicates that the pearls are registered chiefly during the evening, night, and morning hours of local time. The chief maximum occurs during the interval from 0300-0700 hours, local time. If the distribution is considered in terms of universal time, the chief maximum occurs around 0000 hours. In the polar regions, the diurnal distribution of pearls manifests several maxima. The difference in the character of the diurnal distribution in the high and middle latitudes is apparently due to the difference, noted above, the form in which these disturbances are manifested at various latitudes.

Beat-type pulsations frequently are registered simultaneously over a very large latitudinal and longitudinal interval. In connection with this, there arises the question of the possibilities of world-wide excitation of these pulsations and of the regularities of pearl excitation according to universal time. To determine the effect of local and universal time on the excitation of pearls, a diurnal distribution was constructed for the pearls registered in local and universal time at all the stations. In the generalized distribution according to universal time, the main maximum occurs at 1700-2000 hours and two lesser maxima occur at 0100-0200 and 0600-0700 hours. The generalized local time distribution manifests a definite tendency toward the appearance of pearls in the pre-midnight and early morning hours.

Seasonal Course of Pearls. In examining the seasonal course, it is necessary to distinguish between pearls which originate in the course of magnetic storms and are elements of pulsation intervals that diminish by period (Ref. 1), and the pearls which originate on quiet or weakly disturbed days. Obviously the first kind, i.e. pearls registered during a storm or on the day following a storm (which happens quite frequently) will have a seasonal course in common with magnetic storms, with the maxima on the equinoxes. The seasonal course of pearls occurring on quiet days requires special study.

In connection with the relatively small amount of material available concerning pearls[1], the seasonal distribution of pearls at all stations was generalized for the registered cases according to the global regions (Arctic, middle-latitude, and Antarctic). The distribution obtained indicated that in the middle latitudes, the number of cases of pearls during the autumn equinox of 1957 increased sharply. A lower flat maximum was disclosed for the summer solstice and autumn equinox of 1958. For the Arctic the generalized graph showed two maxima: in the spring and autumn equinoxes of 1958.[2]

For the Antarctic region, a flat maximum was obtained which includes the vernal equinox of 1958, the summer solstice (Antarctic winter), and the autumn equinox (the names of the seasons are given with respect to the northern hemisphere).

Thus, in the obtained graphs there was generally reflected a tendency for pearls to originate in the course of magnetic storms. Study

[1] In contrast to pc and pt which are registered practically every day, pearls belong to comparatively rare phenomena.

[2] It should be kept in mind that the majority of the Arctic stations began regular operations only at the end of 1957.

of the seasonal distribution would of course require a large amount of material for each station individually, especially for studying the seasonal course of pearls originating on quiet days.

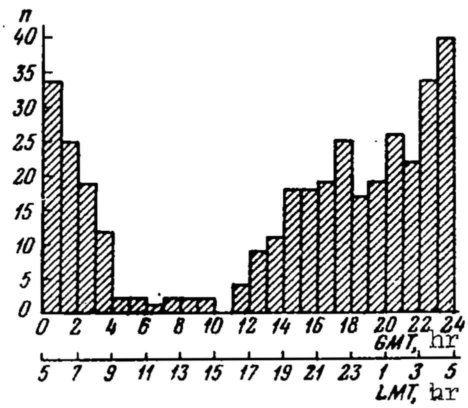

Figure 4. Diurnal course of pearls at the Alma-Ata Station (1952-1953 and 1957-1958).

Geographical Distribution of Pearls. As was already noted, pearls can arise simultaneously in a vast territory, both during the largest magnetic storms and on quiet days. Cases of the simultaneous excitation of these pulsations in the Arctic and the Antarctic regions are rather frequent. In the Table of the Appendix are presented several cases of pearl-type pulsations observed in the northern and southern hemispheres (within a large longitudinal interval), for disturbed and quiet days. In Figure 5 are presented recordings of pearls registered simultaneously at a number of stations.

Relationship of Pearls to Disturbances of the Earth's Electromagnetic Field. It has already been stated above that in the course of magnetic storms intensive pearls arise, the period of which may diminish as the PDP interval develops (Ref. 1). A pearl series has a tendency to originate on the day following a severe magnetic storm.

It has recently been discovered, although no systematic study of this has as yet been made, that pearls registered in the polar latitudes can be looked upon as the immediate precursors of severe magnetic storms (for example, that of 15 July 1959). In these cases the excitation moments of pearls coincide with the moments of the invasion of cosmic particles generated during solar eruptions. The direct comparison of pearl recordings with standard recordings of the magnetic and electrical fields of the earth has provided no indication as to a morphological relationship of pearls (on comparatively quiet days) with any known form of field disturbance (for example, a bay, a train, etc.). Comparison showed that in one case the moment of the emergence of pearls coincides with an absolutely quiet line of slow recording, in another case, with continuous pulsation, (regular or irregular), in a third case with a train or a bay, etc.

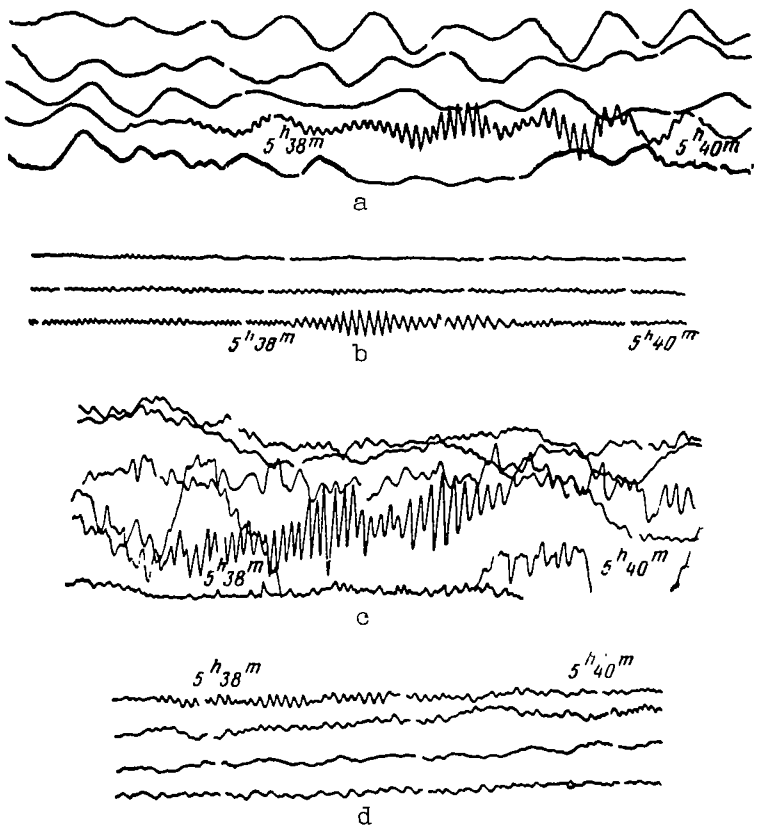

Figure 5. Example of the simultaneous excitation of pearls over an extensive territory on 26 February 1958. a - Yuzhno-Sakhalinsk; b - Hayes Island; c - Chelyuskin; d - Borok.

It should, however, be noted that while pearls do not constitute a permanent fine structure of any known individual form of macroscopic disturbance of the earth's magnetic field, they are with respect to SPP among the basic elements of the largest of magnetic storms.

Conclusion

A new characteristic class of short-period pulsations of the earth's electromagnetic field, pulsations of the beat-type, known as pearls, has been detected at an extensive network of stations. They may originate in the form of individual bursts of 1-2 min duration, or in the form of series of pulsations with a very stable period within the series and a duration up to an hour and sometimes longer.

The pulsations have a sharply limited spectral distribution of from fractions of a second to 4-5 seconds. The amplitude of pearls in the earth currents varies within the limits of from hundredths to tenths of a millivolt per kilometer for the middle latitude stations on quiet days. On disturbed days the amplitude of pearls in the middle latitudes reaches values of unit millivoltsper kilometer, and in the polar regions, values of unit millivolts and tens of millivolts per kilometer. In the magnetic field, the amplitudes of pearls are in the order of several thousandths, hundredths and sometimes tenths of a gamma (for Z). These pulsations can have a local character, and can be excited simultaneously in the Arctic, the Antarctic, and over a great longitudinal interval in the middle latitudes (more than 120 degrees longitude).

Pearls are a characteristic element of the macrostructure of magnetic storms, in particular of pulsation intervals diminishing by period (PDP) that are observed for the largest of magnetic storms. A direct correlation with the development of intensive disturbances in the upper layers has been found for pearls of PDP (Ref. 1). On quiet days, the moment of origin of pearls is not correlated with any characteristic macroscopic form of disturbance of the earth's electromagnetic field. Study of their relationship with phenomena in the upper atmosphere on quiet days has only begun. In a number of cases it has been observed that pearls in the polar latitudes may be regarded as immediate precursors of magnetic storms.

The excitation of pearls is controlled, apparently, both by local and by universal time. On severely disturbed days, control by local time diminishes and pearls are observable simultaneously over a vast area. On normal days, control by local time results in a diminishing of pearls during the local day and in their clear appearance during the local evening, night and early morning hours. It should be stressed, however, that cases of the simultaneous excitation of pearls over large latitudinal and longitudinal intervals have been noted for quiet days as well. The question on the simultaneous excitation of pearls on a global scale requires special study.

In conclusion, the author acknowledges a deep gratitude to the scientific workers who conducted rapid registrations of earth currents during the IGY: N. M. Nikitina, E. P. Zubareva, G. I. Korobkoya, M. V. Okhatsimskaya, V. V. Kebuladze, A. P. Bondarenko, V. G. Dubrovskiy, I. V. Fel'd, L. N. Baranskiy, N. N. Naumenkov, B. V. Bobynin, P. A. Vinogravov, Yu. B. Rastrusin, V. F. Kononkov, R. V. Shchepetnov, and I. I. Rokityanskiy, and also to the scientific associates of the Institute of Terrestorial Magnetism, Ionosphere and Radio Wave Propagation

APPENDIX

SIMULTANEOUS EXCITATION OF PEARLS IN THE ARCTIC, ANTARCTIC AND MIDDLE LATITUDES

Station	Date	Time (GMT)	Period (in sec)
	Quiet Days		
Barentsburg	21 Apr 58	0908-0930	2
Mirnyy	" "	0908-0929	2
Oazis	" "	0908-0929	2
Hayes	20 Feb 58	0537:33-0539:33	2.8
Chelyuskin	" "	0537:39-0539:39	2.8
Irkutsk	" "	0537-0539	2.8
Borok	" "	0537-0540	2.8
Ashkhabad	" "	0538-0540	2.8
Alma-Ata	" "	0537:23-0539:23	2.8
Yuzhno-Sakhalinsk	" "	0537:15-0539:15	2.8
Borok	13 Jun 58	0242:30-0244:30	2
Alushta	" "	0242:30-0244:30	2
Shatsk	" "	0242-0245	2
Chelyuskin	" "	0242-0244:52	2
Lovozero	" "	0242:52-0244:52	2
Barentsburg	" "	0242:30-0245:30	2
Alma-Ata	" "	0246-0248	2
Barentsburg	13 Jul 58	0141-0149	1.2-1.4
Oazis	" "	0140:30-0146	1.2-1.4
Barentsburg	8 Apr 58	0415-0427	5
Mirnyy	" "	0417-0420	5
Oazis	" "	0418-0422	5
Lovozero	16 Sep 58	0119-0151	1.2
Mirnyy	" "	0120-0131	1.2
Oazis	" "	0115-0147	1.2
Barentsburg	12 May 58	0839-0845	1.8-2
Mirnyy	" "	0832-0843	2
Oazis	" "	0832-0845	1.8-2
Chelyuskin	" "	0839-0846	1.8-2
	Disturbed Day		
Lovozero	30 Sep 57	1330-1331	2.5
Mirnyy	" "	1300-1400	2.5
Oazis	" "	1300-1400	2.5
L'vov	" "	1319-1333	2.5
Ashkhabad	" "	1300-1400	2-2.5
Alma-Ata	" "	1300-1400	2.5
Irkutsk	" "	1300-1400	2-2.5
Petropavlovsk-Kamchatskiy	" "	1328-1331	2.5-3

(IZMIRAN), V. V. Novysh and O. P. Grodnicheva. The author also thanks L. Ya. Rukin, technical associate of the Institute of the Physics of the Earth, Academy of Sciences USSR, for the significant work carried out in the processing of the recordings.

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XII. ON THE CHARACTERISTIC INTERVALS OF THE PULSATIONS DIMINISHING BY PERIODS (10-1 sec) IN THE EARTH'S ELECTROMAGNETIC FIELD AND THEIR CONNECTION WITH PHENOMENA IN THE UPPER ATMOSPHERE

by

V. A. Troitskaya and
M. V. Mel'nikova

Investigation of round-the-clock ultrahigh-speed (0.5 mm/sec) recordings of variations of the earth's electromagnetic field has shown that short-period pulsations, diminishing by period (PDP) approximately from 10 to 1 sec (Refs. 1, 2) are observable during strong magnetic storms. The moments of the origination of these intervals coincide with the moments of the origination of polar aurorae in the lower latitudes, and with the beginning of strong disturbances in the ionosphere accompanied by a sharp drop of the critical frequencies of the F2 layer, diffuseness, or complete absorption. The material studied up to the present time leads to the conclusion that the PDP intervals are that morphological type of disturbance of the earth's electromagnetic field which can be used as a criterion of the beginning and development of large-scale disturbances in the upper layers of the atmosphere. Thus, high-speed recordings of the earth's electromagnetic field make it possible to determine on the basis of characteristic combinations of pulsations (interval of PDP), the moments during a magnetic storm at which the most intensive disturbances in the upper atmosphere would begin and terminate.

The character of pulsations in the PDP interval, the sequence of replacement of the pulsation periods, the regularities of PDP excitation according to local and universal time, and also the peculiarities of the latitudinal distribution of PDP are new additional parameters that can be used in investigating magnetic storms, studying the upper atmospheric layers, and examining the peculiarities of the interaction of solar corpuscular streams with the layers of charged particles surrounding the earth.

The characteristic intervals of PDP were observed in high-speed recordings of earth currents (0.5 mm/sec), in the course of analyzing the microstructure of magnetic storms on the basis of round-the-clock recordings made by 17 Soviet stations, 2 of which are located in Antarctica, 5 in the Arctic region, and 10 in the middle latitudes (Ref. 3). In Fig. 1 is presented a diagram of the development of the PDP interval in its optimum expression. The relative duration of the various pulsations is not reflected in the plan. The breaks in the recording denote that the transition of pulsations of one period into the pulsations of another, as a rule, lesser period can follow after some arbitrary time.

Fig. 2 shows photographic copies of recordings of a characteristic pulsation series of which PDP intervals usually consist—the PDP intervals. The interval begins with an irregularly broken section of the recording line (Fig. 2a), against the background of which these originate individual burst or series of comparatively regular pulsations with periods of 6-10 sec (Fig. 2b) arise. Later, series of more or less regular pulsations with lesser periods begin (Fig. 2: c, d, e, f, g.).

Pulsations with periods of 4-1 sec are the most characteristic PDP element, since the pulsations of these periods can continue without damping for tens of minutes. For all pulsations making up the interval, there is a characteristic amplitudinal modulation which often passes into beating-type pulsation. Individual cases of PDP may be distinguished one from another by the predominance of pulsations of one kind or another, and by a somewhat differing sequence of transitions from one period to another.

According to the data obtained up to the present time, one to four PDP intervals may be observed in the course of a magnetic storm. The duration of a PDP interval usually does not exceed an hour although longer cases have been observed. The intervals may follow one another with breaks lasting from tens of minutes to 2-3 hours.

The PDP intervals may have different degrees of development. Sometimes the very first interval contains only irregular pulsations of the recording line (jerks) and some superimposed bursts of long-period pulsations, without a subsequent development of continuous resonant pulsations of lesser period. It is interesting to note that the beginnings of PDP, i.e. irregular breaks of the recording lines with a characteristic sharp entrance (Fig. 2a), are observed considerably more frequently than the phenomenon of PDP in its complete development. They resemble the microstructure of bays and pulsation trains.

All the large storms occurring during the IGY contained PDP intervals. They were expressed most clearly on 4 and 29 September 1957, 11 February, 8 July and 4 September 1958. They were sufficiently characteristic in the storms of 13, 21 September, and 6, 7 November 1957. The development of PDP intervals was somewhat less characteristic in the storms of 26 November 1957, 25 September, 24 October and 4 December 1958.[1]

1 PDP intervals with varying degrees of development are characteristic for any magnetic storm.

In Fig. 3 is shown the origin and development of PDP in 4 and 29 September 1957, 8 July and 4 September 1958 for different stations. The different shadings denote different periods of pulsation.

The magnetic storm of 29 September contains 2 PDP intervals (Fig. 3a), of which the first (1 hour 45 minutes) is approximately

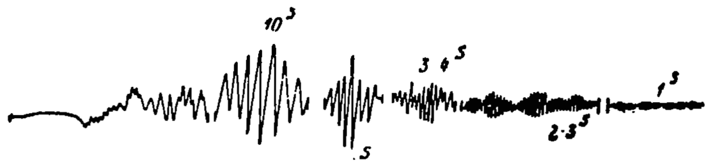


Fig. 1. Scheme of pulsation intervals diminishing by period (T ~ 10-1 sec).

twice as long as the second (around 1 hour). The beginning of the first interval was at 1700 hours, the second at 1938 hours. Both intervals began with irregular pulsations against the background of a broken recording line. Traces of pulsations with periods of about 2 sec are observable in the recordings of a number of stations before the beginning of the second PDP interval.

The magnetic storm of 4 September 1957 includes 2 PDP intervals (Fig. 3b) of approximately equal duration (around 2 hours). The beginning of the first interval was at 1728 hours, the second at 2149 hours. Both intervals began with irregular pulsations against the background of a broken recording line. The irregular part of both PDP intervals is discontinuous (5-15 min), and passes sharply into pulsations of regular form with periods of 4.5—3.5 in the first interval and periods of 2.5 sec in the second. The least pulsation period (1.5 sec) is traceable in the second interval and occupies a large part of it.

The magnetic storm on 8 July 1958 (Fig. 3c) also contained 2 PDP intervals. The first interval began at 1616 hours and continued until approximately 1820 hours. The second interval began at 2040 hours and continued for 1 hour and 20 minutes. In both intervals all elements of the PDP are reliably traced: breaks in the recording line and irregular pulsations, then regular pulsations with periods of 10-8 seconds and 6-4 seconds to pearls with periods of 2 seconds. The development of PDP intervals during the storm of 8 July has been cited for a small number of stations; it was impossible to trace the details of the development of the PDP intervals at other stations due to the severe disturbance. Individual PDP elements are undoubtedly traceable at all stations where recordings of the earth currents were carried on in this period.

The magnetic storm of 4 September 1958 (Fig. 3d) contains four PDP intervals, the first two of which (at 1610 and 1848 hours) did not develop completely and were not presented in the figure. In the first interval (1610 hours) irregular PDP pulsations appear (Fig. 2a), with individual bursts of regular pulsations with periods of 6-8 seconds. The development of the second interval (1848 hours) ended at regular pulsations with a period of 3-5 seconds. The duration of the first interval was 40-50 minutes, and that of the second, slightly over an hour.

During the storm of 4 September 1958, complete development was attained by the third and fourth PDP intervals, which followed one another after a pause of approximately 20 mins. The beginning of the third interval was at 2038 hours, that of the fourth at 2216 hours; the duration of the third interval was about an hour; that of the fourth, about an hour and a half. A peculiarity of this storm are the small periods at the end of the fourth interval (about 1 second) and the disturbance of the sequence of development of this interval in the initial phase where beating pulsations with a period of 1 second are observable among the irregular pulsations.

The development of all the examined PDP intervals at the majority of the stations indicates the practical simultaneousness, over a vast territory, of the beginning and end of pulsations comprising the PDP, i.e., it attests to the excitation of PDP according to universal time. On the other hand, the development of PDP at stations located in the Far East (Yuzhno-Sakhalinsk, Petropavlovsk-Kamcharskiy) indicates a definite effect of local time on the possibility of the appearance of PDP intervals. In the Far East, in a number of cases, only traces of individual elements of PDP are detectable against a background of the SPP typical for a certain hour of the day, or against a background of quiet recording.

It should be noted that the characteristic development of PDP intervals for the examined examples is not observable at the more eastern stations.[1]

The PDP interval is, apparently, a typical middle-latitude

[1] It stands to reason that there are cases (for example, the storms of 13 and 23 September 1957, 11 February 1958) when the development of PDP is better traceable at the eastern than at the western stations.

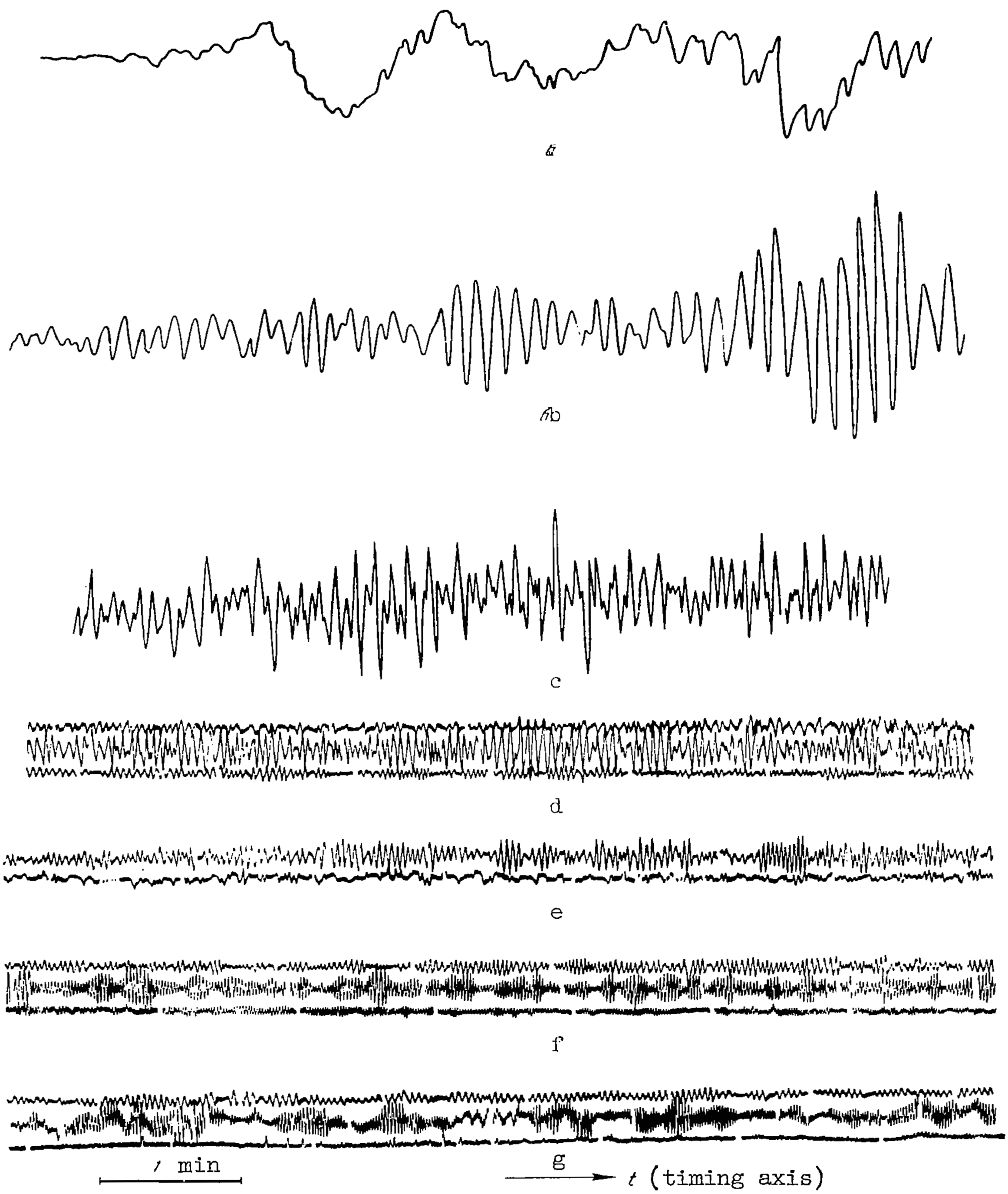


Figure 2. Photographic copies of characteristic pulsations making up PDP intervals -- the PDP elements.

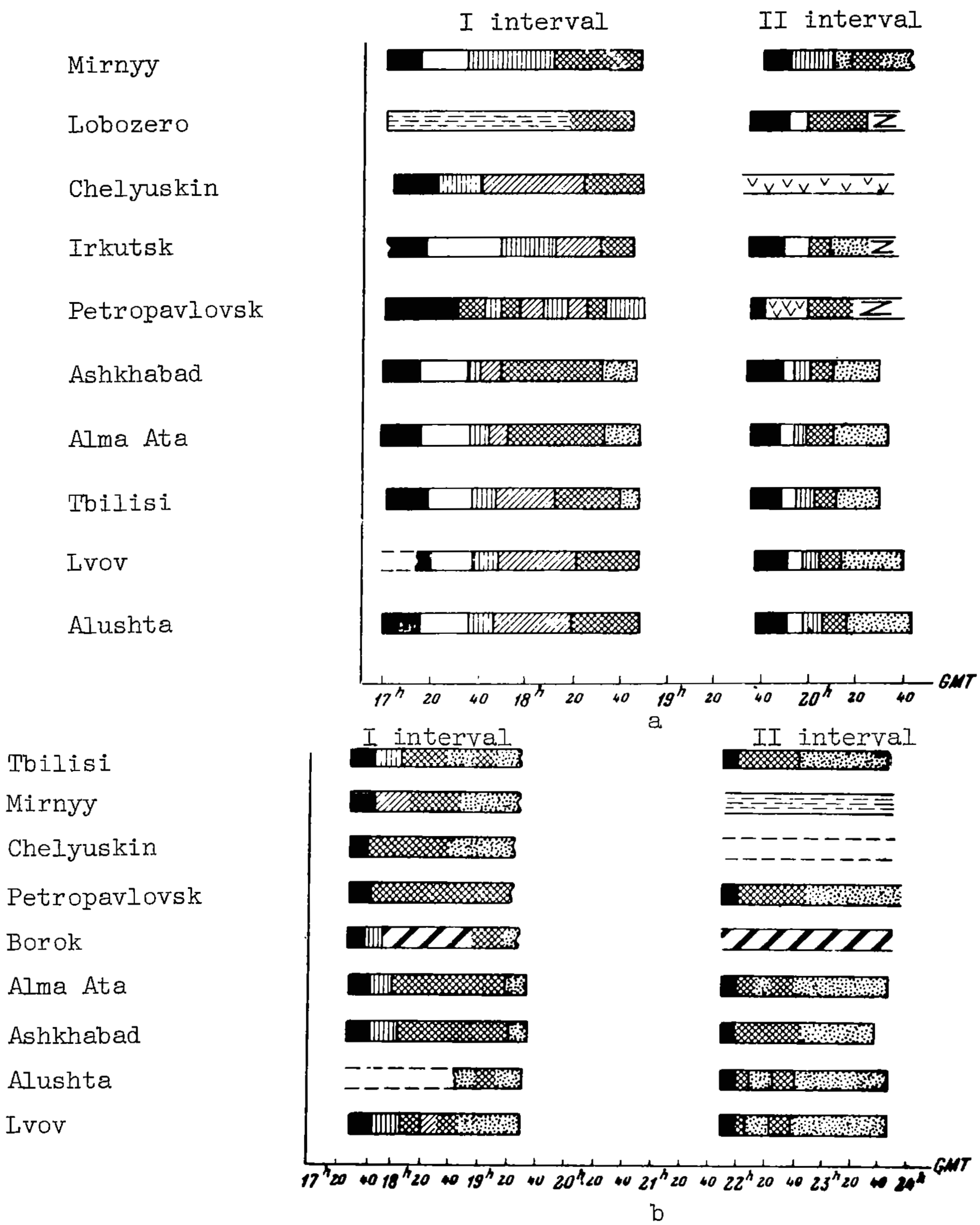
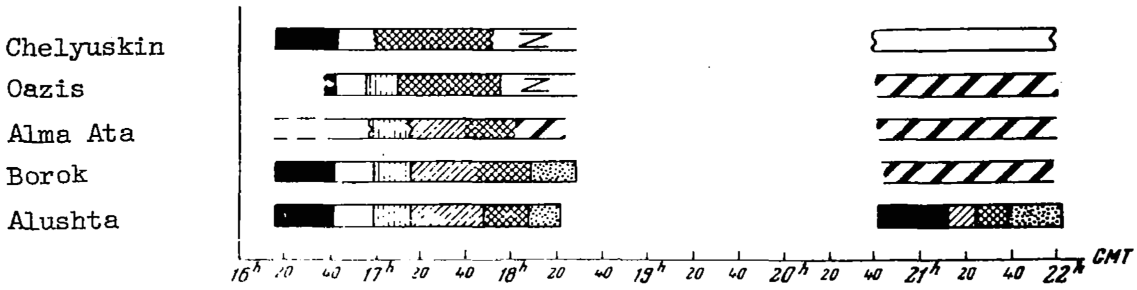
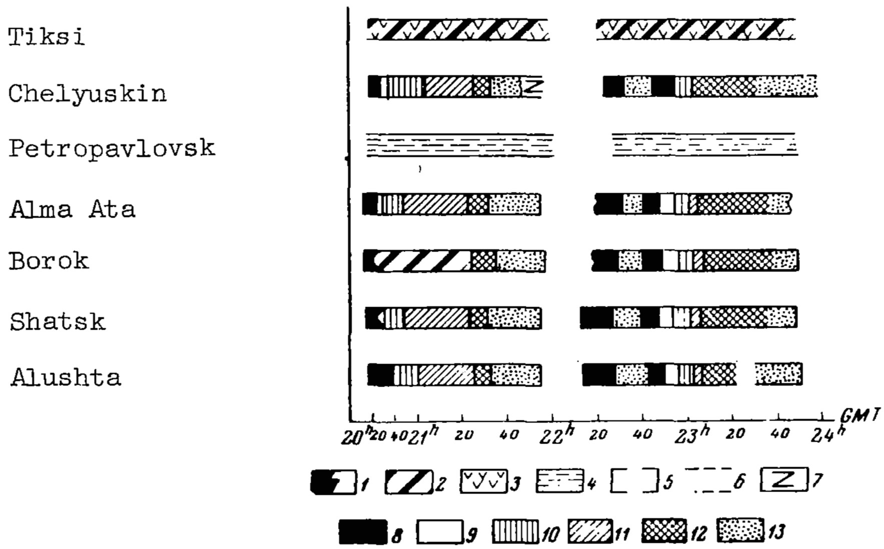


Figure 3. Structure of PDP intervals during magnetic storms on 29 September 1957 (a), 4 September 1957 (b), 8 July 1958 (c), and 4 September 1958 (d). The scheme of the development of PDP by stations is shown by different kinds of shading which denote the various pulsation period in accordance with the arbitrary designations:



c



d

(Figure 3. Continued) 1 - boundary unclear; 2 - disturbed; 3 - interference; 4 - traces of SPP against a background of long-period pulsations; 5 - quiet field; 6 - no recording; 7 - irregular recording line without SPP; 8 - no pulsations; 9 - continuous pulsations with T = 5-10 sec; 10 - continuous pulsations with T = 3.5-5 sec; 11 - continuous pulsations with T = 2.5-3.5 sec; 12 - continuous pulsations with T = 2-2.5 sec; 13 - continuous pulsations with T = 2 seconds or less.

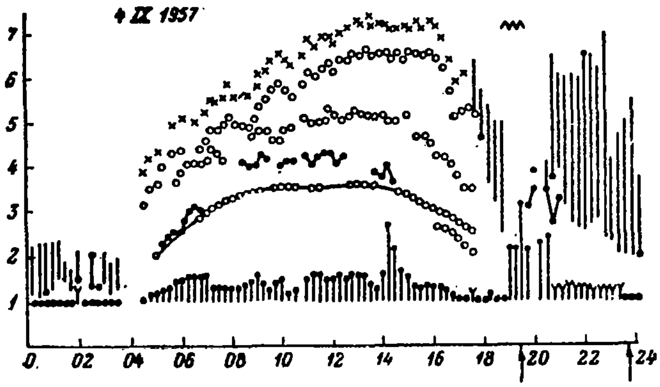
phenomenon. Investigation of the development of PDP intervals at the Arctic and Antarctic stations is often hindered by the highly disturbed nature of the recording. Nevertheless, individual elements of PDP intervals are reliably traceable in the majority of cases at all stations.

Analysis of all the PDP cases examined by us leads to the conclusion that with simultaneous excitation of the PDP intervals, which is probably determined by universal time, their clear appearance is possible within the limits of 6-hour zones in the evening, night, and in the early morning.

Comparison of the moments of excitation PDP with the results of visual observations of polar aurorae in the middle latitudes indicates that the beginning and development of PDP coincides with the origination and development of the polar red glow aurorae.

To illustrate the coincidence of PDP intervals with the origination of polar aurorae in the low latitudes, we present a description of visual observations of polar aurorae on the night of 29-30 September 1957, and also the results of spectral observations of polar aurorae at the Alma-Ata station (Ref. 4). In the two photographs made by the nebular spectrograph of the Shternberg State Astronomical Institute at Alma-Ata on 29 September at 1636 hours (Greenwich Meridian Time) (with an exposure of 30 min) and at 1659 (with an exposure of 2 min) there are no anomalies; the green line is brighter than the red even though the magnetic storm began at 1200 hours (GMT). The photograph made at 1710 hours with an exposure of 6 min yielded a sharp increase of the red line. Visual observations simultaneously indicated that the sky flared up with a bright red glow at the same time. Turning to Fig. 3a it is evident that the PDP began at 1700 hours, i.e., that the moment of its beginning coincided with the beginning of the development of the polar aurora. Further visual observations attest to the fact that at 1939 hours (the moment of the beginning of the second PDP interval), a second outburst of red glow occurred. The spectrographic data also indicate that at this period the red line dominates. Beginning at 2013 hours the intensity of the red line became approximately equal to the intensity of the green line. Visual observations indicate that by 2024 hours the red glow weakened, the color of the sky became bluish. Thus, the red form of the glow ended by the end of the second PDP interval.

In the description of the development of the aurorae on that same day in Odessa, it was reported: columns of red glow appeared for the first time around 1700 hours (GMT) and the second time (most brightly) around 2000 hours (moments close to the beginning of the PDP intervals).



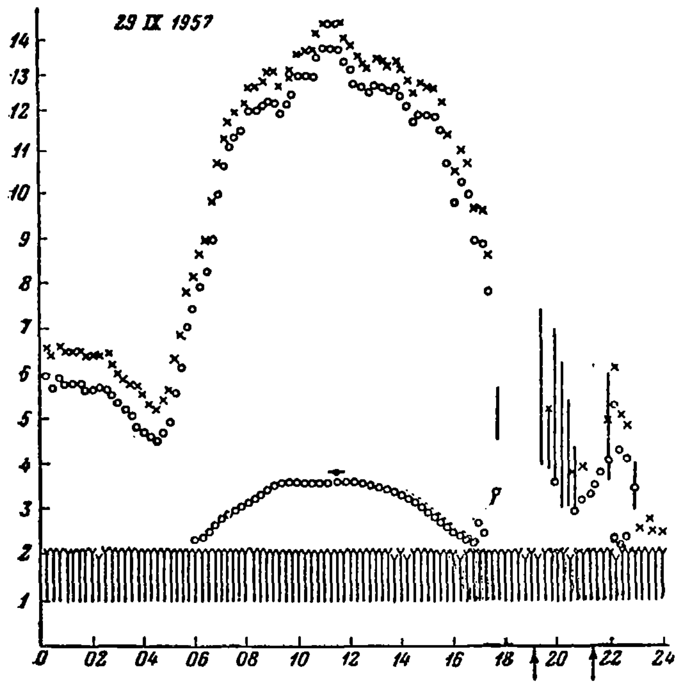


Figure 4. Graphs of the state of the ionosphere at the Moscow Station during magnetic storms. Along the abscissa is plotted the time at 30°E, along the ordinate is plotted the frequency in MC. The vertical lines along the time axis indicate the beginning of the PDP intervals.

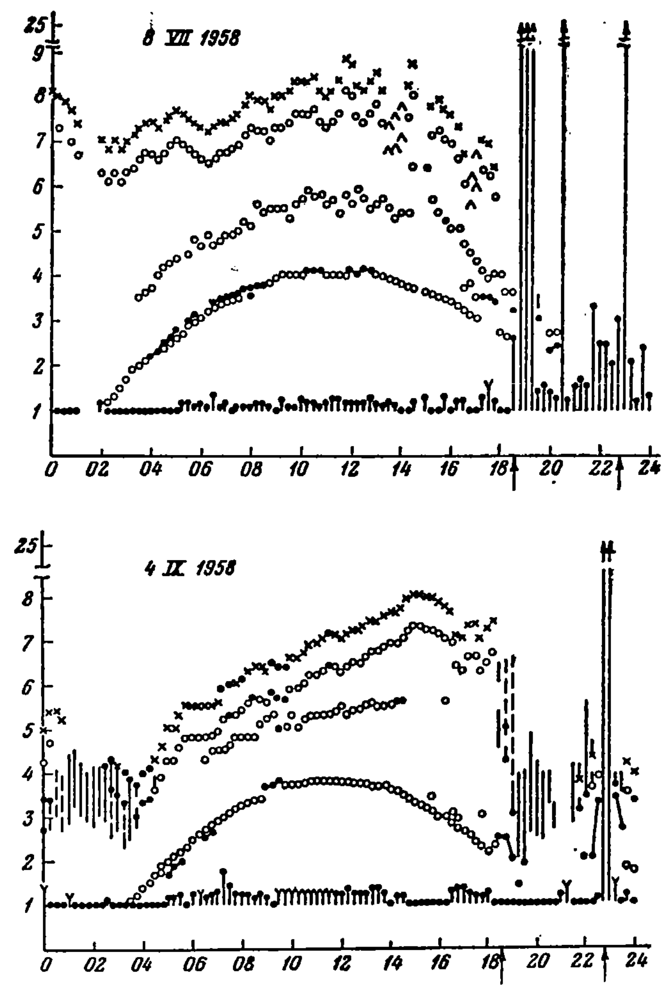


Figure 4. (Continued)

Analysis of the results of visual observations of polar aurorae for the other magnetic storms also showed that the moments of the origination of bright polar red glow aurorae in the middle latitudes coincide with the PDP intervals. The results of visual observations of the polar red glow aurorae in the period of the first interval of PDP of the earth's electromagnetic field for the storm on 4 September 1957 are presented in the table as an example.

Comparison of the PDP intervals with phenomena in the ionosphere indicated a direct correlation between the moments of the excitation of PDP and the initiation of sharp infractions of the normal state of the ionosphere, accompanied by a severe drop of the critical frequencies of the F2 layer. In a number of cases complete absorption took place, or diffusion was observed, simultaneously with the PDP interval. Graphs are presented in Fig. 4 which characterize the condition of the ionosphere at the Moscow station for the magnetic storms of 4 and 29 September 1957, 8 July and 4 September 1958.

Arrows along the time axis denote the beginning of the PDP intervals in the course of a magnetic storm. The graphs show that a sharp infraction of the normal state of the ionosphere coincides with the beginning of the excitation of PDP intervals. Deserving of special attention is the fact that magnetic storms begin several hours before the onset of disturbances in the ionosphere, and only at moments near the beginning of PDP do intensive disturbances of the normal state of the ionosphere originate.

The analysis presented indicates that the PDP intervals are apparently that characteristic morphological element of disturbance of the earth's electromagnetic field in the course of a magnetic storm which is directly correlated with the infractions in the ionosphere and with the development of polar aurorae in the low latitudes. It is interesting to note also that the beginning moments of PDP, for example, for the storms on 11 February 1958 and 13 September 1957, determined on the basis of recordings of Soviet stations, coincide with the moments of the bursts of roentgen radiation in the stratosphere observed by American scientists in Minneapolis and in California.

The moments of the origination of PDP intervals may probably be regarded as moments of the deepest invasion of solar corpuscular streams in the earth's atmosphere. In connection with this, it should be stressed that the moments of origination of the investigated first intervals of PDP coincided with hours close to midday at the geomagnetic pole (1728 hours, 1710 hours and 1616 hours), when the earth is turned to the sun with open force lines and the conditions for the invasion of streams are probably most favorable.

Table

Station	Beginning of PDP interval	Beginning of the polar red glow aurora according to visual observations
Tbilisi (earth currents)	1728 hours	
Adler		1730 hours
Sochi		1730 "
Borok (earth currents)	1728 "	
Urzhum		1730 "
Stalingrad		1725 "
Kazan'		1730 "
Tambov		1730 "
Gor'kiy		1730 "
Ul'yanovsk		1730 "
Kovrov		1730 "
Staryy Oskol		1725 "
Alma-Ata (earth currents)	1728 "	
Lake Tishki (near Chelyabinsk)		1730 "
Perm'		1730 "
L'vov (earth currents)	1729 " .	
Kiev		1740 "

Recordings of PDP intervals may be used not only for isolating and studying the distrubed periods in the upper atmosphere but also for investigating the peculiarities of their development. This form of disturbance was not observed earlier on recordings of the earth's magnetic field, apparently because round-the-clock rapid recording with great sensitivity (in the order of 0.001-0.01 gamma) is necessary for its isolation.

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XIII. SOME REGULARITIES IN THE BEHAVIOR OF THE VERTICAL COMPONENT OF A STABLE (pc) REGIME OF SHORT-PERIOD PULSATIONS OF THE GEOMAGNETIC FIELD

by O. V. Bol'shakova, K. Yu. Zybin, and N. F. Mal'tseva

(This is an abstract of an article originally published in Izvestiya AN SSSR, Seriya Geofizicheskaya, No. 6, 1960.)

The article describes some regularities in the behavior of the vertical component of short-period pulsations of the geomagnetic field observed with fluxmetric induction installations during the first six months of the IGY. The method of processing photorecordings is set forth, as well as that of secondary statistical reduction. It is established that the probability of the occurrence of pulsations with differing periods is unequal, regardless of the hour of the day. The pulsations with periods of 20, 30 and 60 sec predominate. Pulsations with a 50-sec period are least typical for all the stations. The seasonal variability of the frequency spectrum is examined.

The dependence of the occurrence of pulsations with various periods upon the hour of the day (diurnal variation) is plotted. It is established that diurnal variations of the occurrence of pulsations with various periods differ: the time of onset of the extrema is shifted, and the amplitude of the diurnal variations changes.

The diurnal variation of the mean maximum amplitudes of pulsations with different periods is plotted. It is noted that, for each station, the time of onset of the extrema occurs at the same hours, whatever the period may be. It is supposed that the diurnal variation of amplitude values is controlled by local time, and also that the frequency of occurrence of the pulsations is controlled by a more complex parameter than is the amplitude.

It is further noted that at the Borok station, the group of pulsations with 60-90 sec periods is similar in behavior to the pc pulsations, and manifests specific regularities.

In order to reveal the general regularities of short-period pulsations, the term "pc activity," similar to activity according to international geomagnetic characteristics, is introduced. The diurnal and seasonal variation of pc activity is examined. A distinct diurnal variation of pc activity is noted, with clearly expressed extrema. The maximum of pc activity is observed in the daylight hours without regard to the longitude of the station. It is suggested that there exists a latitudinal shift of the pt-activity maximum. Lowering of the level of pc activity is noted during the winter solstice in comparison to the autumnal equinox, and an earlier onset of extrema of the diurnal variation of pc activity is also observed.

Supplementary consideration is given to the connection between the diurnal variation of pc activity and the diurnal variation of "disturbances," i.e., pulsations with a higher amplitude set off both against a background possessing the same period as, and against a background differing in period from the pulsations with a higher amplitude.

XIV. SOME RESULTS OF OBSERVATIONS OF THE VARIATION VECTORS OF THE HORIZONTAL COMPONENT OF THE GEOMAGNETIC FIELD OF THE EARTH

by A. G. Kalashnikov and K. Yu. Zybin

(This is an abstract of an article originally published in Izvestiya AN SSSR, Seriya Geofizika, No. 2, 1961.)

The article describes the method of plotting of the variation vector of the horizontal component of the geomagnetic field H. The article gives results of the study of the H vector behavior in time and space, according to the observation data obtained at the Borok geophysical station of the Institute of Earth Physics, Academy of Sciences USSR.

An azimuth has been determined which keeps strictly to the predominant direction of the fluctuations of vector H (NW 38°); also determined has been a distinct diurnal variation of vector H, the maximum value of whose deviation from a northern direction is attained at 0400-0500 hr universal time. The coincidences of the diurnal courses of the vector azimuths of the variations of the magnetic and electrical (E) natural fields of the earth and their perpendicular position for all the hours of the day are traced.

It is established that the H vector rotates and the directions of the rotation possess a clearly expressed diurnal variation. The rotation of the H vector counterclockwise is observed in the night and morning hours, and the rotation of the vector clockwise is observed in the day and evening hours.

The behavior of the H vector is compared with the behavior of the E vector. It is established that the directions of the changes of the H vector for the given period of time are perpendicular to the directions of the changes of the E vector, while the directions of the terminal points of vectors E and H coincide. The figures formed by the terminal points of the vectors of the variations E and H are similar, and the coefficient of similarity (or the ratio $\frac{\vec{E}}{\vec{H}}$) depends on the pulsation period, diminishing with an increase in the pulsation period.

In conclusion some suppositions are expressed about the mechanism of the origination of the rotatory movements of the variation vector H.

XV. ON THE SHORT-PERIOD VARIATIONS OF THE ELECTROMAGNETIC FIELD OCCURRING SIMULTANEOUSLY OVER LARGE TERRITORIES

by A. G. Kalashnikov and Ye N. Mokhova

(This is an annotation of an article originally published in Izvestiya AN SSSR, Seriya Geofiziki, No. 1, 1960.)

The study of disturbances simultaneously occurringon large territories was undertaken by using the results of the complex registration of the vertical component of the magnetic field H_z, with the fluxmetric installations and of the horizontal component of the earth currents field E_x and E_y at the Borok, Lovozero, Petropavlovsk and Dousheti stations. In the study of long periods, the material of American magnetostatic stations was analyzed.

Pulsations of the impulse, train, and microbay types were clearly distinguishable on the magnetograms and tellurograms due to similarity of shape and simultaneity of occurrence.

The period, amplitude, time of occurrence of H_z, E_x, and E_y, the ratio $\frac{H_z}{\sqrt{E_x^2+E_y^2}}$ for each station, and the amplitude ratios among the various stations were determined. The main result consists in the fact that for every disturbance, the following inequalities are maintained: H_z of Borok < H_z of Petropavlosvsk < H_z of Lovozero. E of Borok < E of Petropavlovsk < E of Lovozero, where

$$E = \sqrt{E_x^2+E_y^2}.$$

$\frac{H_z}{\sqrt{E_x^2+E_y^2}}$ of Borok $<$ $\frac{H_z}{\sqrt{E_x^2+E_y^2}}$ of Lovozero and of Petropavlovsk.

The obtained amplitude distribution cannot be explained by the latitudinal factor. It probably depends on differing geological structures of the regions where the stations are located, on continuous inhomogeneities in the ionosphere, in the upper atmosphere, and on coastal marine electric currents.